Both types of receiver may be used with the line-interlaced as well as the dot-interlaced version of the system. For dot-interlaced reception, additional circuits are required which effectively connect and disconnect the picture tube in synchronism with the corresponding connections and disconnections of the camera tube, described above.

*23. Performance characteristics of the CBS system*

We proceed now to examine the performance characteristics of the CBS system, in accordance with the outline of sections 13 and 14, chapter 2.

*Resolution (sec. 14 (a)).*—For reasons given below (under flicker-brightness relationship), the field-scanning rate of the CBS system must be chosen substantially higher than that of the black-and-white system. The rate used in the CBS demonstrations is 144 fields per second.

In section 7 it was explained that the standard black-and-white television system has a geometric resolution of approximately 200,000 picture elements per frame (two interlaced fields). This corresponds to a field repetition rate of 60 per second and a video band width of 4 megacycles (6-megacyle radio channel).

In the CBS line-interlaced system the geometric resolution is also determined by the number of picture elements in two interlaced fields, but the field repetition rate is now increased to 144 per second. It was explained in section 9 that for a given band width the number of picture elements in a frame is inversely proportional to the field-scanning rate. The geometric resolution of the CBS line-interlaced system is therefore 200,000 times 60/144 or 83,000 picture elements. Thus the higher field-repetition rate decreases the geometric resolution of the CBS line-interlaced system to 60/144 or 42 percent of that of the standard black-and-white system.

In the dot-interlaced version of the CBS system, the resolution is doubled in theory, and very nearly doubled in practice. Thus the resolution of the dot-interlaced CBS color image is about $2\times 83{,}000=166{,}000$ picture elements or 83 percent of the resolution of the standard black-and-white image.

*Flicker-brightness relationship (sec. 14 (b)).*—In a field-sequential color system, such as the CBS system, flicker is a much more difficult problem than in a line-sequential or dot-sequential color system. This follows from the fact that the eye is more sensitive to large-area flicker than to small-area flicker and from the fact that in the field-sequential system, the interruption of the image in changing from color to color occurs over the whole picture area.

To counteract the prominence of large-area flicker, it is necessary to increase the field-scanning rate by a substantial amount. Experience has indicated that, for equal flicker-brightness performance under all conditions, the field-scanning rate of a field-sequential system should be about 3 times that of a black-and-white system. Actually, in the CBS system, the field rate has been increased by the ratio $144/60=2.4$ times, rather than 3 times. The lower value was chosen to preserve as much geometric resolution as possible within the confines of the 6-megacycle radio channel.

It follows that large-area flicker is more prominent in the CBS system than in the black-and-white system. The comparable flicker rates in the two systems are 48 per second in the CBS color system,

(twice the complete picture rate) and 60 per second in the black-and-white system (the field-scanning rate). The difference in the rates is 12 per second. According to the Ferry-Porter flicker law, this difference in flicker rate would allow the black-and-white image to be about 9 times as bright as the color image, for equal visibility of flicker.

Corresponding to these theoretical values are various practical values quoted in the testimony given at the FCC hearing. It was reported that flicker can be held within tolerable levels if the high-light brightness of the CBS color image is not greater than about 25 foot-lamberts, whereas the corresponding limit for the standard black-and-white image is well above 100 foot-lamberts. The 25-foot-lambert figure was quoted for the filter-disk type CBS receiver. In the projection-type CBS receiver, using a long-persistence phosphor in the green image, higher brightnesses were attained within the tolerable limit of flicker.

At the request of the committee, tests of large-area flicker were made by the National Bureau of Standards. The results are given in annex D of this report.

So far as small-area flicker is concerned, the CBS line-interlaced system is not substantially different from that of the black-and-white system, and it may be somewhat superior when the colors transmitted are not too close to saturated red, green, or blue. The dot-interlace version of the CBS system is, on the other hand, somewhat inferior in this respect to the black-and-white system. Small areas (dimensions of the order of a picture element) are scanned at a color-picture rate of 12 per second in the dot-interlaced CBS system.

Interline flicker should be somewhat more pronounced in the CBS system, when colors in the scene approximate the primary colors, because adjacent lines are then laid down at intervals of one-forty-eighth second, compared to one-sixtieth second in the black-and-white system. However, when the colors comprise components of all three primaries in roughly equal amounts (and this is likely to be the case in bright—e. g., white—portions of the scene), adjacent lines are laid down at intervals of one one-forty-fourth second, and the interline flicker is then less noticeable than in the other systems.

*Continuity of motion* (*sec. 14* (*c*)).—Continuity of motion, like flicker, is affected in the CBS system by the composition of the colors transmitted. If the object in motion is displayed in one of the primary colors, the other two primaries being substantially absent, then that portion of the image is illuminated only one-third of the time, and the motion may appear jerky. If two or three primary-color components are present, the illumination is more nearly continuous and the discontinuity is not so pronounced.

In either event, motion is portrayed with sufficient smoothness to satisfy the eye, at color-picture rates in excess of 10 per second. So far as large areas are concerned, this requirement is met by both the line-interlaced and the dot-interlaced versions of the CBS system. In small areas, notably the detail of vertical and horizontal edges of objects, the dot-interlaced version of the system may display ragged edges on an object in rapid motion.

*Noncompatible and convertible nature of the CBS system* (*sec. 13*).—The fact that the field-scanning rate of the CBS system must be substantially higher than that of the black-and-white system leads

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to a most important difference in receivers designed for the two systems. In the black-and-white system, the vertical (field) scanning occurs at a rate of 60 per second, and the horizontal scanning at a rate of 15,750 per second (30 frames per second, each having 525 lines). In the CBS field-sequential system, the vertical (field) scanning occurs at 144 per second, and the horizontal scanning at 29,160 per second (72 frames per second, each of 405 lines).

The respective values in the two systems are so different that receivers built for black-and-white reception cannot be adjusted to scan at the higher rates required for the CBS color system, unless modifications are made in the receiver scanning circuits. This fact is the root of the "compatibility" argument. The cost of modifying existing receivers to make them operative on both sets of scanning standards may be substantial, and no reliable data have been submitted as to what this cost would be. However, by modifications of the circuits and the addition of a rotating disk, existing sets with picture tubes less than 12½ inches diameter can be converted to color reception. Thus the CBS system is convertible but not compatible.

*Effectiveness of channel utilization (sec. 14 (d)).*—We have previously noted that both the line-interlaced and the dot-interlaced CBS systems have a flicker-brightness performance somewhat lower than that of the black-and-white system. The line-interlaced version displays resolution which is substantially lower than the black-and-white value. The dot-interlace version has poorer performance so far as small-area flicker and small-area continuity are concerned, but achieves resolution not markedly below that of the black-and-white system. The dot-interlace system makes substantially more effective use of the channel and is to be preferred, on this account, to the line-interlaced version of the system.

The nature of the compromise, adopted to fit the CBS system into the 6-megacycle channel, is determined principally by the large-area flicker effect. Since the color sequence is introduced by changing the color of the whole image at once, it is necessary to increase the field rate by a substantial amount, relative to the black-and-white system, and to lower the geometric resolution in proportion.

It may be argued, therefore, that the field-sequential scheme is less effective in channel utilization, because it devotes a disproportionately large amount of spectrum space to the reduction of flicker, at the expense of a substantial loss in resolution. Stated in another way, the use of the field-sequential technique, with dot-interlace, results in a picture having less geometric resolution (about 83 percent of the black-and-white value) and lower large-area flicker-brightness performance (brightness at flicker threshold about one-ninth the black-and-white value, for a given phosphor decay characteristic). Finally, the fact that the mixed-highs technique cannot be used in the field-sequential system has the effect of lowering the channel utilization, relative to that of a dot-sequential color system using mixed highs.

*Color fidelity (sec. 14 (e)).*—There is, as noted previously, no basic difference in the color fidelity of the three color systems. This statement assumes a proper choice of filters, phosphors, and light sources, proper color balance and gradation, and freedom from superposition defects. In practice, as the systems were demonstrated to the committee, the CBS system displayed superior color fidelity to the other two systems when filter-disk receivers were employed. This

superiority is explained by better color balance (the same area is scanned in all three primary colors in the CBS camera, and in the filter-disk type CBS receiver as noted below), and by more accurate registration between the primary color images.

At the request of the committee, tests on the fidelity of color reproduction by both the CBS and the RCA systems were undertaken by the National Bureau of Standards. Results are given in annex E of this report.

*Superposition defects* (sec. 14–f).—A noteworthy characteristic of the field-sequential system is the fact that the color sequence occurs at a slow rate (144 per second), compared with the CTI line-sequential system (15,750 per second) and the RCA dot-sequential system (10,800,000 per second). The slow color sequence, while making the flicker problem comparatively serious, has the compensating advantage of allowing the color sequence to be introduced mechanically by the rotating filter-disk method. Since, in this method, filter segments are placed successively in front of the camera tube and picture tube, it is necessary to employ only one scanned surface for all three primary colors. The CTI and RCA systems require in the camera a separate image for each of the three primary colors, and similar images in the receiver.

Since only one scanned surface is used in the CBS filter-disk system, maintenance of proper registration between the primary color images is a simple matter. The optical elements are common to all three images, so optical misregistration cannot occur. Electrical registration is assured if the scanning pattern of each field is precisely congruent to those preceding and following it, and this requirement is readily met, provided only that the scanning system is adequately protected from stray magnetic and electric fields. The absence of registration defects is a noteworthy characteristic of the CBS system, compared with the present state of development of equipment in the two other color systems.

The other types of superposition defects are, however, more pronounced in the CBS system than in the others, due to the inherent nature of the scanning process. Color break-up and color fringing are detectable when either the eye or the image are in rapid motion.

*Depiction of fine detail.*—The CBS system cannot, by virtue of the nature of the scanning method used, take advantage of the mixed-highs principle. In compensation for this fact, and to improve the resolution, a circuit technique known as "crispening" has been developed by CBS. This is a method of causing the vertical edges of objects to appear more sharply defined. This technique is not unique to the CBS system, but may be used in any system to achieve the same result. It is believed, therefore, that the use of the crispening technique is not a significant difference between systems.

### 24. Summary

The essential characteristics of the CBS field-sequential system are as follows:

(*a*) The CBS system scanning standards are not compatible with the black-and-white scanning standards. This requires modification of existing black-and-white receivers, and additional complication in receivers of the future, to permit reception on both sets of scanning standards.

(*b*) The line-interlaced version of the CBS system has substantially poorer resolution than the black-and-white system. The dot-interlaced version has slightly poorer resolution than the black-and-white system. The crispening technique, applied to the CBS system, improves its resolution. However, this technique, applied to other systems, would improve their apparent resolution also.

(*c*) The large-area flicker-brightness performance of the CBS system is inferior to that of the black-and-white system. This means that CBS color image cannot be as bright, by a factor of 5 to 10 times, as the black-and-white image, for equal freedom from flicker. The dot-interlaced version of the CBS system, operating at the low color-picture rate of 12 per second, has a small-area flicker performance (inter-dot flicker) not as good as the black-and-white system.

(*d*) The color fidelity of the CBS system, as demonstrated, is superior to that of the other color systems. This superiority is due to the maintenance of better color balance and more accurate registration, both of which are implicit in the use of but one scanned surface in the camera and one in the receiver. Much of this advantage is lost in the electronic version of the CBS receiver, since three surfaces are necessary at the receiver.

(*e*) The effectiveness of channel utilization is satisfactory in the line-interlaced version, and is good in the dot-interlaced version. The impossibility of employing the mixed-highs technique lowers the channel utilization with respect to the dot-sequential color system.

(*f*) Existing receivers with picture tubes of 12½ inches and smaller diameter can be converted to color reception, but at an appreciable cost.

## Chapter 5

### THE RCA DOT-SEQUENTIAL SYSTEM

#### *25. Introduction*

The information in this chapter is based on the testimony submitted by the Radio Corp. of America to the FCC during the color-television hearing, and on demonstrations of the RCA system witnessed by members of the committee prior to May 1, 1950.

#### *26. The RCA scanning pattern*

Figure 4 shows the manner in which the RCA dot-sequential color television image is scanned. The basic scanning pattern is identical to that of the standard black-and-white system, i. e., the image consists of 525 lines, scanned at a rate of 60 fields per second. About 490 lines of the image are active, and about one-eightieth of a second is available for the active scanning of all the picture elements in a single field.

Each line of any one field in the image consists of dots in the three primary colors. The dots are arranged from left to right in the sequence red, blue, green. The space between two dots of the same color—e. g., green—is equal to the width of the dots; consequently the dots tend to overlap each other.

On successive scannings of the same line, the dots are shifted, so that the position of a dot of given color falls midway between the positions of two dots of the other two colors, scanned on the preceding frame. Consequently at the end of two frames (four fields), every point on each line has been scanned in all three primary colors. The color picture rate is accordingly 60/4=15 color pictures per second.

The positions of the dots on adjacent lines, scanned on successive fields, is shifted so that a dot of one color falls midway between the dots of the other two colors on the adjacent line. Consequently the whole area of the image, after four fields have been scanned, is covered with a uniform distribution of dots in the three primary colors.

The scanning of the RCA dot-sequential image is of the dot-interlaced variety, as may be appreciated by considering dots of one color only, e. g., green. As noted above, two green dots on one line are separated by a blank space, in which dots of red and blue are fitted, with some overlap. On the next scanning of that line, the space midway between two green dots is filled in by a green dot. The same sequence applies, on successive scanning of any given line, in respect to the red and blue colors. As a consequence of this dot-interlaced technique, the resolution of the RCA image is approximately twice as great as it would be if the interlacing was confined to the lines alone. The dots of any one color are laid down along each line at a rate of 3.58 million per second.

*27. Essential apparatus of the RCA system*

The camera, used in the demonstrations of the RCA system, employs three image orthicon camera tubes, one lens and a set of color selective mirrors which separate the light from the scene into three colors. Red light enters one camera tube, blue light the second tube, and green light the third tube. The sensitive plate of each camera tube is scanned in identical fashion, at the normal scanning rates of the standard black-and-white system, i. e., 525 lines per picture, 60 fields per second. In this fashion three complete images are televised, one for each of the primary colors. The optical and electrical adjustment of the camera must be such that each of these images is precisely congruent to, and properly oriented with, the others.

When the camera views a scene having fine detail, the output signal of each camera tube contains signal components up to 4 megacycles (actually components of higher frequency may be present but are not transmitted through the system). To take advantage of the mixed-highs principle, the signal from each camera tube is divided into two groups of frequencies. The components of frequencies above 2 megacycles, representing the finest detail in the image, are combined at the outputs of the three camera tubes. This mixed signal represents the finest details of the picture in tones of gray.

The signal components lower than 2 megacycles, corresponding to the respective primary colors, and representing all details of larger size, are transmitted separately. The structure of the image is depicted in color except for the smallest details, which are shown in tones of gray.

The three color signals are transmitted in interspersed fashion by means of a switch which connects and disconnects each camera tube in sequence to the transmitter. This switch (which operates electronically since no mechanical switch could operate at the high speed required), makes and breaks the connection to each camera in rotation at a rate of 3.58 million times a second. Each time a camera tube is connected, it generates a dot of the respective color. When disconnected, that camera is inactive, leaving a blank space in that color. As the switching progresses, the blank spaces between dots of one color are filled in by dots of the other two colors.

The net result is a sequence of overlapping dots along each line, in the sequence red, blue, green, each dot being somewhat larger than a picture element. Superimposed on the colored dot signal is the mixed-high signal, including details from the size of one picture element to several picture elements, in tones of gray.

Two types of receiver have been demonstrated by RCA. In the first type, three picture tubes are employed, one for each of the primary colors. By means of a high-speed electronic switch, like that at the transmitter, each tube is connected and disconnected from the receiver. This switch operates in strict synchronism with the transmitter switch. So the green tube, for example, is connected to the receiver only while green dots are being generated and is disconnected while the red and blue dots are generated. Consequently, on the face of the green tube, a dot-interlaced image appears which represents the image picked up by the camera tube which scans the scene in green. This image does not contain the finest detail of the picture, but the mixed-highs signal is also applied to each picture tube, through the switch, so that the fine detail is in fact present on the face of the green tube. The same arrangement is provided for the red and blue tubes, so that they reproduce images representative of those picked up by the red and blue camera tubes respectively, together with the mixed-highs component, derived from all the camera tubes.

The three primary-color images are combined by viewing them through a system of color-selective mirrors, which reflect light of a given primary color while transmitting light of the other two colors. Care must be taken to assure that the images on the three picture tubes are precisely the same size, have the proper orientation with respect to one another, and are congruent throughout. If these requirements are met, the primary-color images combine in register before the eye of the observer. The fine detail of the combined image, being present in equal amount in all three primary-color images, appears in tones of gray.

The second type of receiver employs but one picture tube, which is viewed directly. The viewing screen of this tube is composed of a very large number of small precisely alined areas, each area consisting of a cluster of three types of phosphor, which glow in the three primary colors. Each cluster represents a picture element which may be made to glow in any one of the primary colors. In one type of the tube demonstrated, three electron guns are used, one gun for each primary color. The guns are so positioned that the electron beams strike the screen at slightly different angles, having passed through perforations in a metal plate parallel to, and just behind, the screen. The angle of each beam is such as to cause it to fall on the phosphor of each cluster which glows in the color assigned to that beam. Thus each picture element in the image may be made to assume any primary color, by activating one gun as it passes that particular cluster, the other two beams remaining inactive during that interval.

To re-create the color image in the single-tube receiver, a high-speed switch, like those previously described, applies the picture signal to the three electron guns in sequence. The timing of the switch is such that the gun associated with one color becomes active at the instant corresponding to the time the camera tube of the same color is connected at the transmitter, and similarly for the other two colors. In this manner the clusters along each line in the image are caused to

assume the color and intensity associated with the sequence of red, blue, and green dots transmitted over the system.

The single-tube receiver employs but one scanned surface, so the optical and electrical requirements for proper registration are considerably simpler than in the three-tube type of receiver. Moreover, the electrical and optical components of the single-tube receiver are substantially simpler.

*28. Performance characteristics of the RCA system*

The performance characteristics of the RCA system, based on the outline of sections 13 and 14, chapter 2, are as follows:

*Resolution (sec. 14 (a)).*—The resolution of the system must be considered in two categories: the mixed-highs component and the color components. In the mixed-highs component, the maximum picture-signal frequency is 4 megacycles, the same as that of the black-and-white system. Since the time for scanning the active portion of each field is also the same, one eightieth of a second, the number of picture elements per field is the same, about 100,000, and the total resolution (contained in two successive fields) is 200,000 picture elements. This fine structure is, of course, depicted in tones of gray.

The color components, considered individually, each have a maximum picture signal frequency of about 2 megacycles. In the dot-interlace type of transmission each cycle produces one picture element. Moreover, in accordance with the dot-interlace technique, all the dots in any one color are laid down in four consecutive fields, or in one-fifteenth of a second. When account is taken of the portion of the image blanked off, this time is reduced to one-twentieth of a second. Consequently 2,000,000 green dots are scanned per second, or 100,000 green dots during the complete color picture period. Thus, nominally, the resolution in each color is one-half that of the black-and-white image.

Actually the resolution in the individual primary colors is not as high as 100,000 dots because there is a certain amount of dilution of each color by the other two colors. This dilution occurs because the signal corresponding to one color dot overlaps that corresponding to the adjacent color dot by about 50 percent. This phenomenon, known as "cross-talk," has the effect of causing a part of the color values to combine into shades of gray, much in the manner of the mixed-highs portion of the image. The net effect is that details of width from one to eight picture elements are reproduced in shades of gray, whereas all larger portions of the image are reproduced in their component colors.

As indicated in section 12, chapter 2, the superimposed fine detail in the mixed-highs method of transmission provides a substantial economy in the use of the channel, without appreciable degradation of the color or tonal values of the image. In theory, therefore, the resolution of the RCA system is equal to that of the black-and-white system. It should be noted, however, that the tricolor tubes demonstrated had a resolution of 117,000 picture elements, rather than the 200,000 elements of which the system is theoretically capable. This limitation was imposed by the number of phosphor clusters on the screen and perforations in the metal plate which could be accommodated in the tube. Refinements in the design and construction of the tricolor tube may remove this limitation in the future.

In passing it may be mentioned that the tubes as demonstrated were laboratory models of a special design which may involve considerable difficulty in adapting to factory production. At present one of the most urgent needs of all color television systems is for a three-color receiver tube adaptable to quantity production. Besides RCA a number of others are known to be actively engaged in seeking solutions to this important problem, notably Dr. E. O. Lawrence, of Berkeley, Calif., and Dr. C. W. Geer, of Los Angeles, Calif.

*Flicker-brightness relationship (sec. 14 (b)).*—The large-area flicker-brightness performance of the RCA system is equal to that of the black-and-white system, since the systems employ the same field rate, 60 per second. The small-area performance is inferior to that of the black-and-white system, however, since a given picture element is scanned in all colors at the comparatively slow rate of 15 per second. Accordingly interdot and interline flicker are present at lower light levels than are the corresponding small-area flicker effects in the black-and-white image.

In early demonstrations of the RCA system a prominent form of dot crawl was evident along vertical or nearly vertical boundaries in the image. In later demonstrations, the geometry of the dot scanning had been altered to minimize this effect, and dot crawl was not then evident.

*Continuity of motion (sec. 14 (c)).*—Since the field scanning rate of the RCA system is equal to that of the black-and-white system, the continuity of large objects in motion is the same. The continuity of small objects (of the dimensions of a few picture elements) is adversely affected by the low color-picture rate of 15 per second. This shortcoming is inherent in the dot-interlace system, and is parallel to the small-area effect noted in section 23, chapter 4, as applying to the dot-interlaced version of the CBS system.

*Compatible nature of RCA system (sec. 13).*—Since the line and field scanning rates of the RCA color system are identical to those of the black-and-white system, the two systems are compatible so far as scanning goes. Consequently a black-and-white rendition of RCA color transmission can be received on existing and future sets designed for black-and-white reception only, without change in the scanning circuits of these receivers. Moreover, the presence of the mixed-highs component in the color transmission assures high resolution in the black-and-white rendition. The black-and-white rendition of the RCA color transmission has higher resolution and better flicker-brightness performance than do the black-and-white renditions of the CTI and CBS systems.

*Effectivenes of channel utilization (sec. 14 (d)).*—The RCA system makes highly effective use of the channel because it employs both the principal spectrum-saving techniques—dot-interlace scanning and mixed-highs transmission.

*Color fidelity (sec. 14 (e)).*—As noted elsewhere in this report, proper choice of mirrors, filters, and phosphors permits the RCA system to achieve satisfactory color fidelity. However, if color balance and accurate superposition of the primary-color images are not maintained, the color fidelity suffers. The color fidelity demonstrated in the RCA system was considered by the committee to be not as satisfactory as that of the CBS system. The larger colored areas in the RCA images were not always uniform in hue and saturation. This may have been caused by differences in the spectral responses of the

three camera tubes. Color distortions noted in small areas are explained by overlapping and cross-talk between the color signals, described above. In the early demonstrations of the RCA system, gradual shifting of colors with time was observed, due to uncontrolled shifts in the relative positions of the interspersed color dots along each line. In the later demonstrations, these shifts were controlled by improvements in the synchronization of the high-speed switch of the receiver, and the colors were then found to be free of such variations with time. (See annex E for results of National Bureau of Standards tests on color fidelity of the RCA system.)

*Superposition defects (sec. 14 (f)).*—Of the three principal superposition defects—color break-up, color fringing, and faulty registration—only the last is present in the RCA system. Registration is more difficult to maintain in the RCA system than in the other systems. This follows from the fact that three separate camera tubes are used, introducing the possibility of optical and electrical errors in the size, orientation, and congruency of the primary images as transmitted. In the three-tube type of receiver, these possibilities of improper registration are present also in the receiver. In the single-tube receiver, faulty registration may occur between the scanning of the three electron guns, but optical misregistration does not occur.

*Depiction of fine detail.*—The dot-sequential color system, alone of all sequential systems, can use the mixed-highs method of depicting fine detail. In the RCA dot-sequential system, no color information is transmitted at frequencies above 2 megacycles whereas the fine detail, transmitted by the signal from 2 to 4 megacycles, is shown in shades of gray.

### *29. Summary*

The essential performance characteristics of the RCA system are as follows:

(*a*) The RCA system scanning standards are compatible with the black-and-white scanning standards. Consequently a black-and-white rendition of the RCA color transmission can be received on receivers built for black-and-white reception, without modification of their scanning circuits. Moreover, the characteristics of the RCA color system are such that the quality of the black-and-white rendition may be equal to that of standard black-and-white reception, in resolution and large-area flicker-brightness performance.

(*b*) The RCA color image has an over-all resolution approximately equal to that of the black-and-white system. The finest details are depicted in shades of gray, while larger details are rendered in color. The color transmission has sufficiently fine detail that, when the gray-tone detail is added to it, the apparent resolution of the image as a whole is approximately 200,000 picture elements.

(*c*) The large area flicker-brightness and continuity performance of the RCA system is equal to that of the black-and-white system. The small-area performance in these respects is somewhat inferior, due to the fact that the color-picture rate is 15 per second, half the corresponding rate in the black-and-white system.

(*d*) The color fidelity of the RCA system suffers to a certain extent from uneven color balance in large areas. Overlap and cross-talk between the color components, and faulty registration, affect the color fidelity in small areas.

(e) The effectiveness of channel utilization of the RCA color system is the highest of all the systems discussed in this report.

(f) Existing receivers cannot be converted to color reception in the RCA system, except at a substantial cost.

## Chapter 6

### COMPARISON OF SYSTEMS AND CONCLUSIONS

*30. Introduction*

To avoid confusion, each of the foregoing three chapters has been confined to a discussion of one of the proposed color systems, with a minimum of comparative comment. The plan of the discussion in each chapter follows the same pattern, however, so it is possible to bring together comparably the data and conclusions on the performance of the three systems. This comparison has been set forth in chart form, in the accompanying "Tabular summary of performance characteristics." Explanatory comments are given below.

*31. Comments on the tabular summary*

The committee is of the opinion that the essential differences among the three proposed color systems are embodied in nine categories, listed alphabetically at the left of the tabular summary, and defined in sections 13 and 14, chapter 2, as follows: Adaptability, color fidelity, compatibility, continuity of motion, convertibility, effectiveness of channel utilization, flicker-brightness performance, geometric resolution, and superposition defects.

This list purposely omits consideration of certain peculiarities of apparatus such as mechanical versus electronic operation of the receiver color-sequence device, limitation of size of image, and limitation of angle of view. These matters once loomed large in the competitive consideration of the systems, but they have become progressively less prominent as the development of the systems has proceeded. It appears, in fact, that all of the systems may use a tri-color tube to advantage, and this fact puts all three systems on a par with respect to all-electronic receiver operation, size of image, and angle of view. Moreover, such differences are not fundamental, either in the transition stage during which color service is introduced to the public or in the long run as the color service consolidates its position.

The performance characteristics listed in the tabular summary, on the other hand, are believed by the committee to be fundamental, either because they reside in the nature of the scanning process, or because (as in the case of adaptability, compatibility, and convertibility) they are matters of importance during the transition from black-and-white service to color service.

Under some of the main characteristics are listed a number of subdivisions. These subdivisions are not necessarily of equal importance; they merely represent items on which system performance displays a significant difference. For example, under geometric resolution, the total number of picture elements per frame is more fundamental than either the vertical or horizontal values of resolution considered separately. To aid the reader, the subdivision believed by the committee to have outstanding importance within each main category is marked with an asterisk (*).

No attempt has been made to place relative emphasis on the main categories, which are listed alphabetically to avoid any connotation of relative importance. The emphasis on main categories must be assigned at the highest level of administrative decision, taking into account the economic, political, and sociological factors, as well as the technical factors, involved.

The difficulty of placing this emphasis can be well illustrated by such questions as: Is compatibility (preservation of existing investment) more important than convertibility (converting existing investment)? How do each of these compare with effectiveness of channel utilization (conservation of the public domain) or geometric resolution (providing the maximum flexibility to program producers in choice of subject matter, range of action, and field of view)? Answers to these vexing questions must be found but they are not properly the concern of technical specialists.

So much for the basis of the listings. Opposite each performance characteristic, the committee has placed a verbal or numerical index to the relative performance of the three color systems. These indices represent technical judgments, based either on evident fact, well-established theory, or on the subjective reactions of the committee members to the demonstrations. For the most part, the basis of the committee's judgments will be found in the preceding chapters of this report. But the subjective reactions are difficult to analyze, and the terms "excellent," "good," "satisfactory," "fair," "poor" are, in the last analysis, merely words on which the committee was able to agree as being most indicative of relative performance. The final column in the table indicates the system whose performance is, in the opinion of the committee, superior in each category or subdivision. Where two systems share a superior position, both are listed in alphabetical order.

It is the belief of the committee (1) that this table, with the accompanying text of the report, provides a sound basis for a technical decision among the three systems, and (2) that the only missing element is the relative weight to be accorded each main category. When such weights are assigned, a preponderance of advantage for one system over the others can be found.

The main conclusions reached by the committee have been stated at the outset, in chapter 1. These favor a color service based on the six-megacycle channel, the service to be limited to one of the sequential systems (dot, line, or field).

### *32. Comments on Possibilities of Future Developments*

This report would not be complete without one additional observation, namely that all the systems are subject to improvement as a result of further technical and operational development. The process of improvement will go on in each system until the decision between them is handed down, so long as the proponents and other members of the industry continue to expend manpower and resources on their development.

However, the prospect for future improvement is not of equal magnitude in each system. This is a matter of evident importance in setting standards, since the standards may be expected to be in use for a long time after their full potential has been realized. The net long-term good to the public is thus greatest in that system which can be expected to reach the highest pitch of performance during the

next few years. Such technical advances, presuming a choice of one system in the immediate future, will be limited to those matters capable of improvement within the framework of the then-established standards.

It is the opinion of the committee that the CBS system has progressed furthest toward full realization of its potentialities, within the confines of the field-sequential system. It is not likely, for example, that the color fidelity will improve beyond the highly satisfactory state now achieved. Equally, the CBS system is not likely to improve substantially its channel utilization beyond that achieved in the dot-interlaced version of the system. Nor is the flicker-brightness performance capable of substantial improvement, except by methods equally available to other systems, once the picture rate is established at 24 color pictures per second.

The CTI system, being less fully developed, has somewhat greater possibility of future improvement, particularly with respect to correction of faulty registration and small area color distortions, and the development of convertible receiver circuits using a tricolor tube. But in other respects the CTI system cannot reasonably be expected to overcome certain inherent limitations imposed by the choice of scanning method. These include the difficulty of avoiding interline flicker and the impracticability of using dot interlace (at a color picture rate of 5 per second, which is too low for satisfactory rendition of small areas and sharp edges).

The RCA system also has considerable opportunity for improvement within the confines of the scanning standards proposed for this system. The registration of the color images, and the balance of the color values in both large and small areas can be expected to improve substantially with advances in camera design. Convertible circuits, to convert existing sets to color, using the tricolor tube and auxiliary components, can be developed.

The systems discussed above are confined to those developed and demonstrated by their proponents, CTI, CBS, and RCA. An additional demonstration of a dot-sequential system was viewed by the committee. The Hazeltine Electronics Corp. demonstrated a technique known as constant-luminance sampling, which considerably reduces the visible effect of noise and interference in a dot-sequential color image. This demonstration also provided conclusive proof of the efficacy of the mixed-highs technique, in that a video channel of 4 megacycles, carrying a mixed-highs, dot-sequential transmission was found to offer substantially the same quality of image as a 12-megacycle channel carrying an equivalent simultaneous color transmission. The committee concludes that the Hazeltine developments are an important contribution to the dot-sequential system.

The present state of development of each system has been reached through the efforts of single organizations working in competition. Once the decision is reached among the systems, all that effort, plus additional effort from other quarters, can be applied to the one system then chosen. It may then be found that the real limit to future progress is that imposed by the nature of the scanning standards, not by present equipment limitations or present relative costs.

On this account, the final conclusion of the committee is that principal importance should be attached to those fundamental capabilities

and limitations which relate to the choice of scanning method. These fundamentals have been discussed at length in this report and listed in detail in the tabular summary. Other factors, relating to the present performance and costs of apparatus, deserve consideration, but, in the opinion of the committee, such matters should take second place in the technical assessment of the systems.

Respectfully submitted.

E. U. CONDON, *Chairman.*
S. L. BAILEY.
W. L. EVERITT.
D. G. FINK.
NEWBERN SMITH.

*Tabular summary of performance characteristics*

| Performance characteristic | System | | | | | Superior system |
|---|---|---|---|---|---|---|
| | Standard black-and-white | CTI color | CBS color | | RCA color | |
| | | | Line-interlaced | Dot interlaced | | |
| Adaptability | | Not needed | Adaptable | Adaptable | Not needed | CTI; RCA. |
| Color fidelity: | | | | | | |
| *Large areas | | Satisfactory | Excellent | Excellent | Satisfactory | CBS. |
| Small areas and edges of objects | | Fair | do | do | Fair | CBS. |
| Compatibility: Quality of image rendered on existing sets | | do | Not compatible | Not compatible | Excellent | RCA. |
| Continuity of motion: | | | | | | |
| *Large objects | Excellent | Good | Good | Good | Good | (All comparable) |
| Small objects | Good | Fair | do | Fair | do | CBS (line); RCA. |
| Convertibility | | Not easily convertible at present. | Convertible 12½-inch tube diameter maximum. | Convertible 12½-inch tube diameter, maximum. | Not easily convertible at present. | CBS. |
| Effectiveness of channel utilization | Good | Good | Satisfactory | Good | Excellent | RCA. |
| Flicker-brightness relationship: | | | | | | |
| *Large areas | Excellent | Excellent | Good | do | do | CTI; RCA. |
| Small areas | Good | Fair | do | Satisfactory | Good | CBS (line); RCA. |
| Interdot flicker | Absent | Absent | Absent | Fair | Fair | CTI; CBS (line). |
| Interline flicker | Good | Poor | Good | Good | Good | CBS; RCA. |
| Geometric resolution: | | | | | | |
| *Number of picture elements per color picture | 200,000 | 200,000 | 83,000 | 166,000 | 200,000 | CTI; RCA. |
| Vertical resolution | 490 lines | 490 lines [1] | 378 lines | 378 lines | 490 lines | RCA. |
| Horizontal resolution | 320 lines | 320 lines | 185 lines | 370 lines | 320 lines | CBS (dot). |
| Superposition performance: | | | | | | |
| *Registration | | Fair | Excellent | Excellent | Fair | CBS. |
| Color breakup | | Excellent | Satisfactory | Satisfactory | Excellent | CTI; RCA. |
| Color fringing | | do | do | do | do | CTI; RCA. |

*See explanation on p. 36.

NOTE 1.—This is the geometric resolution; the apparent vertical resolution is considerably less, due to interline flicker.

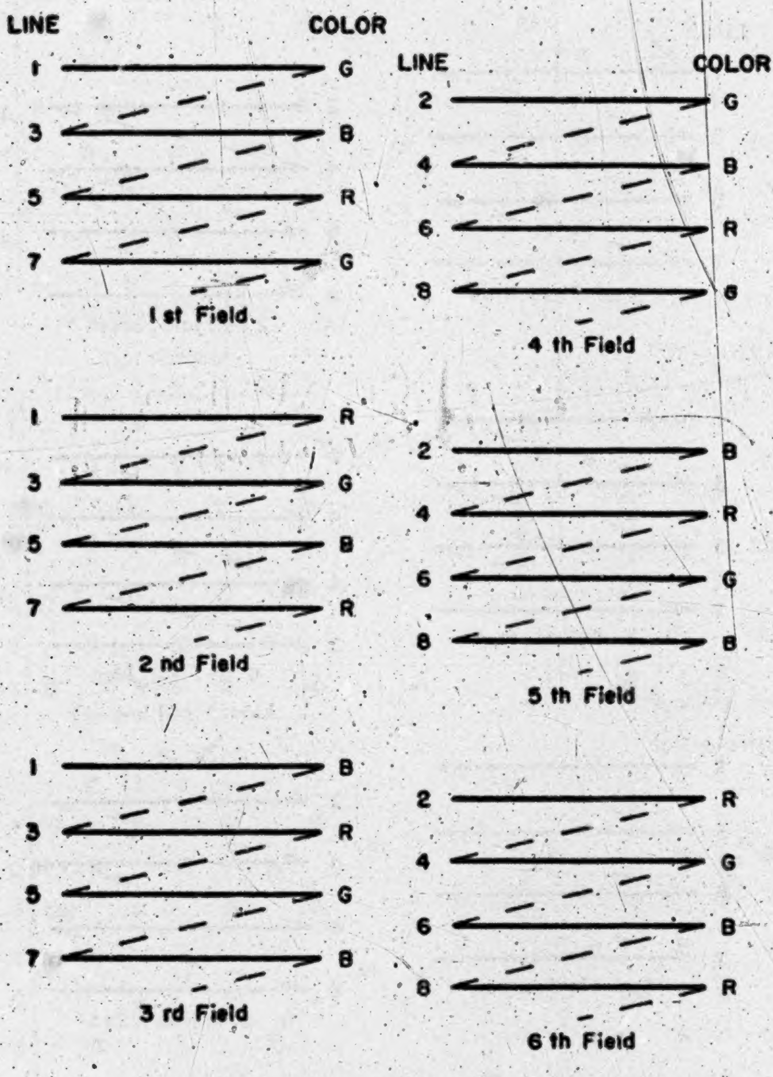



Figure I. Scanning pattern for CTI line sequential color television system
(Only first eight lines of the fields are shown)

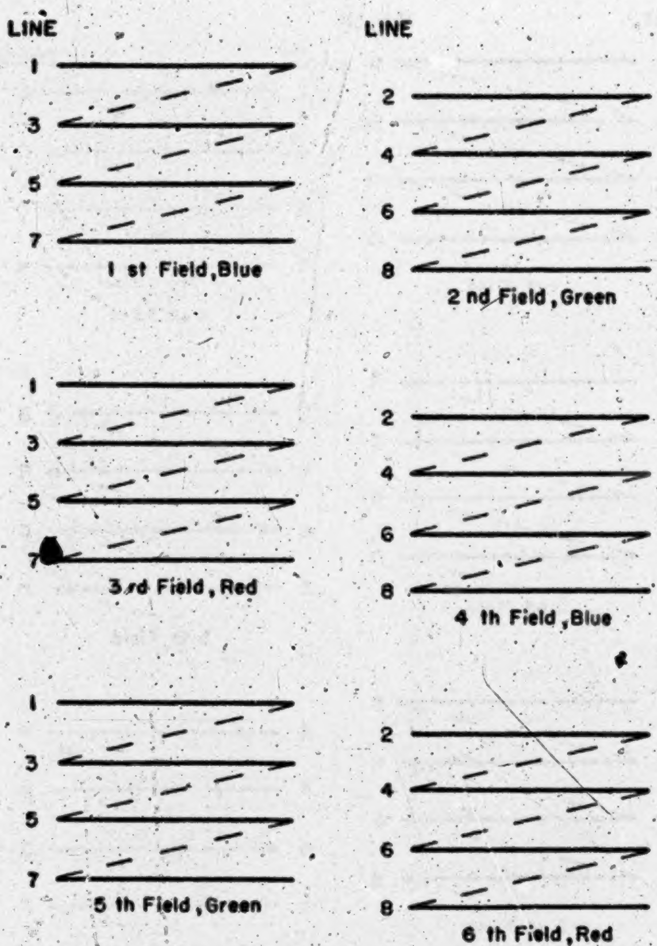



Figure 2. Scanning pattern for CBS field sequential color system line interlaced (Eight lines shown)

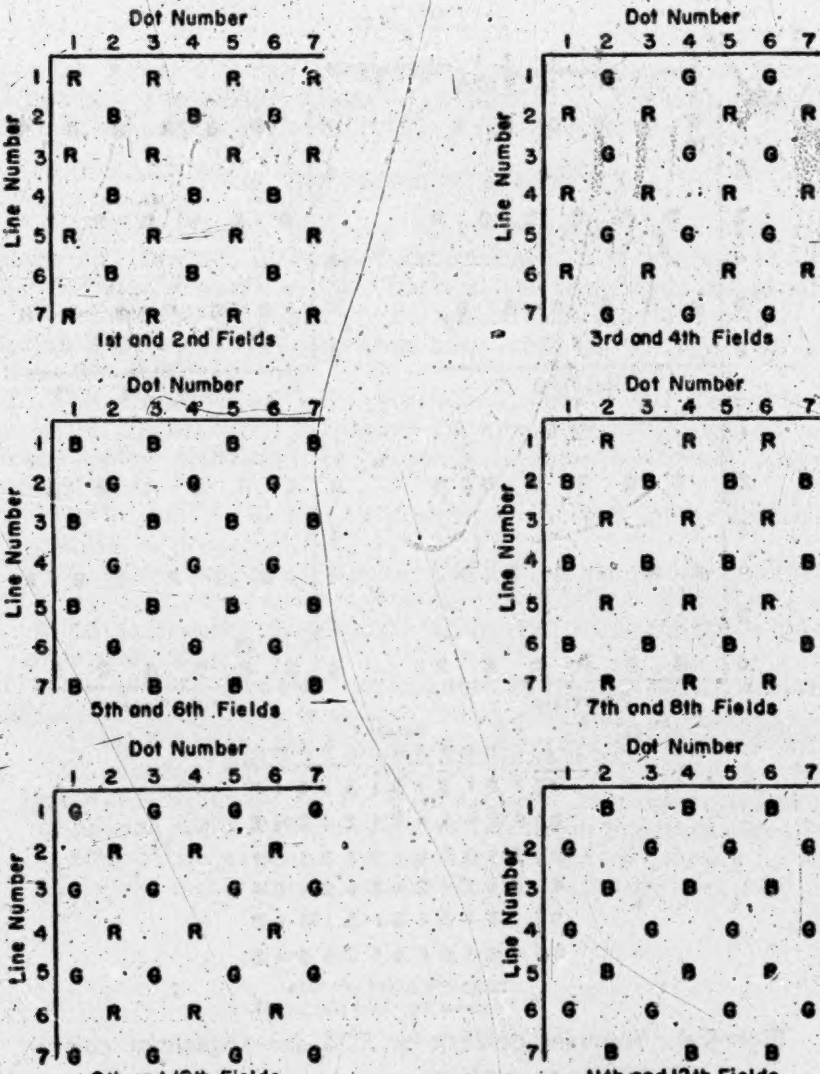
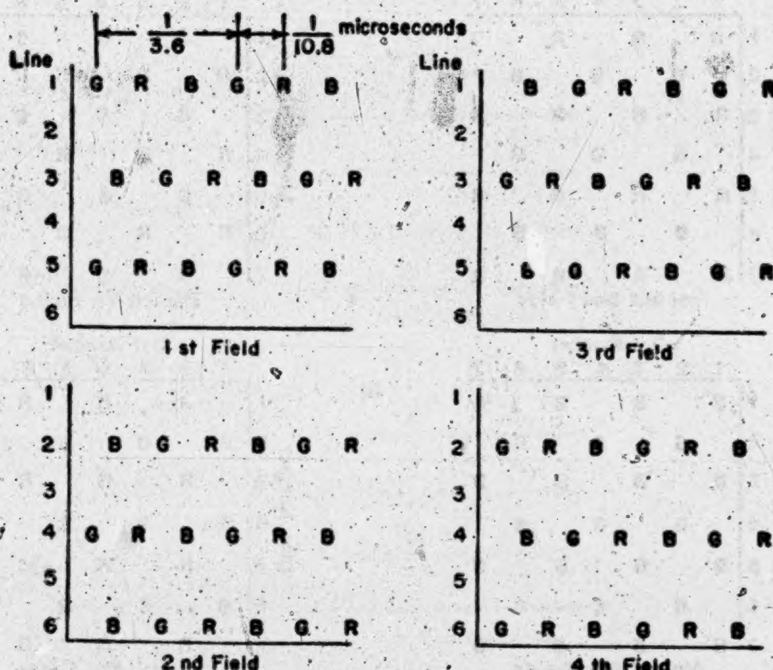



Figure 3. Scanning pattern for CBS field-sequential color system, dot interlaced (Seven lines and seven dots shown)




color

| Line | G | B | R | G | B | R | G | B | R | G | B | R |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 |
| 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 |
| 3 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 |
| 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 |
| 5 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 | 1 | 3 |
| 6 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 |

complete color picture
(figures are field numbers)

Figure 4. Scanning pattern for RCA dot-sequential color-television system
(Only first six lines of fields are shown)

# ANNEX A

## Excerpt From Federal Communications Commission Notice of Further Proposed Rule Making (FCC 49-948, Mimeo No. 37460, Adopted July 8, 1949), Appendix A

### II. TRANSMISSION STANDARDS

A. The Commission proposes that the transmission standards for channels 14 through 55 as well as for channels 2 through 13 shall be those standards which are set forth in the Standards of Good Engineering Practice Concerning Television Broadcast Stations under heading 2 entitled "Transmission Standards and Changes or Modifications Thereof."

B. The Commission will give consideration to proposals for a change in transmission standards on channels 2 through 55 looking toward color television or other television systems. Any such proposal shall—

1. be specific as to any change or changes in the transmission standards proposed; and
2. shall contain a showing as to the changes or modifications in existing receivers which would be required in order to enable them to receive programs transmitted in accordance with the new standards.

C. It is proposed to consider changes in transmission standards for channels 2 through 55 only upon a showing in these proceedings that—

1. such system can operate in a 6-megacycle channel; and
2. existing television receivers designed to receive television programs transmitted in accordance with present transmission standards will be able to receive television programs transmitted in accordance with the proposed new standards simply by making relatively minor modifications in such existing receivers.

## ANNEX B

NATIONAL BUREAU OF STANDARDS,
*February 2, 1950.*

The Honorable EDWIN C. JOHNSON,
*Senate Office Building, Washington, D. C.*

DEAR SENATOR JOHNSON: Herewith for your information is a report drafted by our color-television committee. This report deals only with some aspects of the frequency-allocation problem rather than with color-television systems as such. As I have indicated, we shall probably not have a report on color systems until sometime after the Federal Communications Commission demonstrations have been concluded.

The subject of the present report is, however, pertinent to the general television problem and represents the considered opinion of our committee regarding the frequency-allocation problem. I believe you and the members of your committee may find this material helpful.

The report assumes a knowledge of the general set-up of the frequency-allocation structure in this country, and does not contain much background material on this. If you think that a more general background statement might be of assistance to the members of your committee in considering this problem, we should be glad to furnish one.

I have marked this report "confidential" only to insure that it would not be released unless and until you wish. If you do not advise me to the contrary, I shall do the same with other reports also.

Sincerely yours,

E. C. CRITTENDEN, *Acting Director*.
For E. U. CONDON, *Director*.

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### STATEMENT BY THE SENATE ADVISORY COMMITTEE ON COLOR TELEVISION

The plans for expansion of the television service, whether for additional black-and-white stations or for a color service, must be evaluated in terms of the radio spectrum now reserved for television and other services. Television broadcast stations are currently allocated in 12 channels in the VHF spectrum in the following bands: 54–72 megacycles, 76–88 megacycles, 174–216 megacycles.

In expanding the television service it would appear to this committee that it would be highly advantageous to allocate additional VHF channels between 72 and 300 megacycles. But the space in the VHF spectrum is currently occupied by, or nominally allocated to, other services. These are—

| | Megacycles |
|---|---|
| Government aeronautical navigation and non-Government fixed | 72–76 |
| FM broadcasting | 88–108 |
| Aeronautical navigation and communication | 108–144 |
| Amateur | 144–148 |
| Aeronautical communication | 148–152 |
| Police | 152–156 |
| Nongovernment fixed and mobile | 156–162 |
| Government fixed and mobile | 162–174 |
| Government fixed and mobile | 216–220 |
| Amateur | 220–225 |
| Government aeronautical communication and navigation | 225–400 |

In view of this extensive occupancy of the VHF spectrum by non-television services, the FCC allocated a portion of the UHF spectrum, from 475 to 890 megacycles, for experimental television service, looking toward the development of improved television systems, including high-definition black-and-white and color systems. The FCC has recently issued a proposal to allocate a large segment of the UHF band to commercial black-and-white television broadcasting. The proposal, to be debated shortly in hearings before the Commission, is to allocate approximately 42 channels, each 6 megacycles wide, extending from 475 megacycles to 727 megacycles (or from 500 to 752 megacycles, if the band 475–500 megacycles is allocated to common-carrier fixed-mobile communications).

The proposal to allocate UHF channels is open to a number of serious objections which stem from differences in the performance of transmitters and receivers and in the propagation of radio waves. The available power of transmitters and the sensitivity of receivers are lower, in any given state of the art, in the UHF band than in the VHF band. The performance of the UHF system is impaired further than the VHF system by natural impediments to transmission over the earth's surface. These technical factors have important implications, which may be summed up in the statement that UHF television stations cannot cover as large an area (by a factor of the order of three times) as can VHF stations of the same effective radiated power.

The effect on the extent of the service to the public is manifest. In the first place, areas which might be covered by VHF stations cannot be covered by the same number of UHF stations. A second effect of a UHF allocation which is against the public interest is the tendency to foster monopoly. In areas of dense population, such as the eastern seaboard, a VHF station can reach an audience much larger than can an equivalent UHF station. Accordingly there is serious doubt that a UHF station could, under these circumstances, compete with the VHF stations in the same area. The limited number of stations on the existing 12 VHF channels would then operate at a substantial competitive advantage.

These disadvantages of a UHF allocation may have to be faced, provided that no additional VHF channels can be found. But to the extent that space in the VHF spectrum could be transferred to the television service from other services, the technical, social, and economic shortcomings of UHF television service could be obviated. All the future needs of television may not be satisfied by additions to the VHF allocation. But with even a small addition (e. g., 6 channels) it is possible that an adequate public service can be achieved, both as to coverage and for fostering competition, without the necessity of the extensive UHF allocation proposed by the FCC.

This committee is concerned primarily with the technical factors underlying a color-television service, and is not in a position to recommend specific changes in the VHF allocation. Moreover, the committee wishes to emphasize that the transfer of spectrum facilities from one service to another involves judgments which transcend technical factors. Such judgments must be based on sound technical knowledge, but they involve also the far more difficult determination of the needs of the various services, their established positions and investments, and the quantity and quality of the service they render to the public and the national security. No technical group can

properly undertake judgments of the latter type. They must be made on a high administrative level, by a group of judicial merit, having knowledge of, and properly responsive to, the needs of all the radio services.

It is the considered opinion of this committee that the distribution of the VHF and UHF regions of the spectrum to various services has not been carried out in the past on the basis just suggested. This failure has stemmed from the fact that no Government agency has been given the authority or responsibility to make a judicial review of the use of the entire portion of the spectrum involved. Two groups, operating with different procedures and policies, have been responsible for the main features of the allocation. These are the FCC, which allocates frequencies to non-Government services, and the IRAC (Interdepartment Radio Advisory Committee) which allocates frequencies to Government, including military services and, in addition, allocates frequencies for assignment by the FCC to non-Government services. These groups have not operated, during peacetime, under a common policy and the IRAC has not reviewed, in the manner employed by the FCC for non-Government requirements, the needs of all Government and non-Government services. Unless and until such a review is carried out, at an administrative level sufficiently high to command the respect and cooperation of the industries and Government departments affected, serious doubt will remain that the allocations, as they now stand, are for the maximum benefit of the public and the national security.

While this situation exists, this committee is faced with a difficult choice in its deliberations. It may assume, on the one hand, that a review of the allocations to both Government and non-Government services should be made, and will in fact be made by an appropriate Government agency existing or to be set up, before the proposed expansion of television facilities takes place, and that such a review would probably result in the allocation of additional VHF channels. Alternatively it may assume that the creation of an administrative body to review the allocations, its deliberations and the preparation of its findings, would take so much time that the expansion of television service should not be delayed so long. In the latter event, the committee has no alternative but to proceed within the terms of reference now proposed by the FCC, even though these terms may be faulty.

Since the members of the committee believe this to be a matter of great importance, not only to the future of the television service, but of other radio services as well, they respectfully bring the matter to the attention of the Senate Interstate Commerce Committee and request guidance in the matter.

## ANNEX C

UNITED STATES SENATE,
COMMITTEE ON INTERSTATE AND FOREIGN COMMERCE,
*February 22, 1950.*

Mr. E. C. CRITTENDEN,
*Acting Director, National Bureau of Standards,*
*Washington D. C.,*

MY DEAR MR. CRITTENDEN: This will acknowledge receipt of your letter of February 2, to which was appended two copies of a statement by the Bureau of Standards' special Senate advisory committee on color television, dealing with the question of spectrum allocations for television use. We are most grateful for this statement in which you assert that the proposed allocation appears to pose a problem for your committee in its ultimate findings. You ask for guidance therefore as to whether your committee should make its report on the basis of the existing proposed utilization of both VHF and UHF channels, or whether it should report on the assumption that additional channels contiguous to the present VHF television channels will be allocated.

I have delayed a reply to your letter anticipating developments which might clarify this basic question. The appointment last week by the President of an over-all Communications Policy Board, directed to study, primarily, the frequency use and allocation problem is designed to correct the situation you describe with respect to the present policy of IRAC frequency determinations.

Nevertheless, it seems to me that the Bureau of Standards committee studying the color question could well make its report on the basis of the proposed allocation of the Federal Communications Commission to employ both UHF and VHF. In fact, it would appear to me that your own findings should not be materially altered by whatever band of frequencies ~~are to~~ be used, since you are concerned primarily with the stage of development that color has reached.

However, your comments with respect to the proposed allocations are extremely interesting and they raise the question as to whether it would not be wise for a Bureau of Standards committee to examine just what are the possibilities of eventual use of the frequencies from 72 megacycles to 300 megacycles for additional television channels. Such a study should be made independently of the color study just as the Federal Communications Commission has separated the two items and, it would seem to me, should concern itself primarily with the degree of use that has been made by the various Government services of all, or a substantial part, of these frequencies. In short, to what extent have equipments been engineered for the use of these frequencies by such service as "Government aeronautical fixed" and to what extent, by large contract orders for equipment, have the Government services committed themselves to the use of these frequencies. At the same time, my suggested study might well

include exploration of the UHF frequencies, based on propagation surveys already made or being made, to determine to what extent it is feasible or practicable to make use of these UHF frequencies for television or for other commercial services. I am aware that considerable experimentation is presently being carried on by industry in this field but it would serve a useful purpose to have an unbiased evaluation by a scientifically expert public agency upon which the Congress might rely for technical information.

I am sure you are aware that originally the Commission made clear that the "permanent home of television" was to be in the UHF and that it was allocating VHF frequencies for television use on a temporary experimental basis. Under this original plan, the Commission is consistent today in exploring the use of the UHF for television. If the Commission were to give consideration to moving it out of the VHF now, the tremendous growth of the art would incur revolutionary adjustments.

Your arguments against operation of television simultaneously in both the VHF and UHF appear to me to be cogent and valid. It is my earnest hope that this issue will be resolved one way or the other, but possibly not until we know more about the probability of moving the other existing VHF services out of that area. Therefore such a study as I have suggested the Bureau undertake would prove vital in future consideration of the problem. In view of the tremendous expenditure of time, money, and energy by agencies of government having superior priority over private users to utilize these VHF frequencies, we should not minimize the obstacles.

Meanwhile, it would appear that your committee should make its color findings on the basis of the Commission's allocation now whatever they may be. The report of February 2, as well as any subsequent reports, should continue to remain confidential.

Very sincerely yours,

Ed. C. Johnson, *Chairman.*

# ANNEX D

## Report on Tests of Flicker in Color Television

(By T. H. Projector, National Bureau of Standards)

### I. SCOPE OF TESTS

Television receivers, both monochrome and color, are subject to various imperfections symptomatically visible as imperfections of the image viewed on the screen. Among these are a group of imperfections which may loosely be described as flicker. It is the purpose of this report to describe tests made of a particular one of these imperfections: the cyclic variation of the brightness of the image associated inherently with the field and frame frequencies and with the kind of color synthesis and analysis used.

Tests have been made to date on the Columbia Broadcasting System's color television system only. This system is a "field sequential" system with a field frequency of 144 per second and a frame frequency of 24 per second, or 6 fields per frame. The fields are successively red, blue, and green. Because of line interlace, two cycles of the three colors are required to complete a frame. The horizontal sweep frequency is 29,160 per second. The field colors are obtained with a 6-segment wheel rotating at 24 revolutions per second.

### II. TEST MATERIAL

One CBS table-model color television receiver was delivered to this Bureau in January 1950 for test purposes. It was equipped with a 7-inch CR tube and a magnifying optic yielding a magnified image of the screen approximately the size of a 10-inch tube screen. This receiver was used for physical measurements of the variation of brightness with time. Some preliminary measurements of subjective flicker were made on this instrument but the main group of measurements were made on one of the SKF console receivers located at the Walker Building, where it was used for public demonstrations. The measurements were made at the Walker Building rather than at this Bureau in order to assure optimum reception conditions and thereby to limit flicker to that which is inherent in the system.

### III. PHYSICAL MEASUREMENTS OF BRIGHTNESS VARIATION

To measure the variation of the brightness of the screen with time, an electron multiplier, with a correction filter yielding approximately the ICI "Standard Observer" luminosity response, was used. The field of view of the photomultiplier was limited optically to a square area with sides approximately one-seventh of screen width. The output of the multiplier was amplified and fed into the deflection system of an oscillograph. The sweep frequency of the oscillograph was

adjusted to approximately 24 per second, so that the oscillograph presented a curve of the average brightness of the square portion of the television screen viewed by the multiplier versus time for one complete frame.

The regular CBS broadcast test pattern was used for the test. Curves of all four test pattern colors, red, blue, green, and yellow, were obtained, as was a curve for white. The results are shown in figure 1. It should be noted that the color of the patterns could be altered easily by manipulation of the brightness and contrast controls of the receiver. These were adjusted before photographing the curves to give the best over-all effect, but the results should be considered qualitative only.

It is evident from the figure that the decay time of the phosphor is quite short. The relative vertical spread of the trace near the peaks indicates that the decay time is of the order of a fraction of the time of one horizontal sweep. Evidently then, any small area of the television screen receives periodic sharp pulses of light at intervals of one-one hundred and forty-fourth second. These pulses vary in intensity in accordance with the color composition and brightness of the area and will, on viewing, vary in color because of the interposition of the sequential filters.

## IV. SUBJECTIVE FLICKER MEASUREMENTS

Because of the complex way in which the images are formed, previous work on flicker was not considered directly applicable. In addition, while there has been a considerable amount of work done on critical flicker frequencies (the frequency at which flicker vanishes), very little has been done relating to the observer's subjective judgments regarding a given amount of flicker. Accordingly, this part of the test was divided into two parts. First it was necessary to determine a flicker-tolerance scale for the observers used in the test and then to determine where on the scale the observers considered the color television set to be.

### *A. Flicker-tolerance scale*

In order to obtain a flicker-tolerance scale, a flicker box was constructed. This box had an opal glass window of the approximate form of a 10-inch television screen at one end. The window could be illuminated from behind so as to present for view a simulated television screen of uniform adjustable brightness. Through the use of a sector disk, the brightness of the window could be varied cyclically in a simple way, and the frequency of these cycles could be adjusted to any desired value. One-hundred percent modulation was used in this test.

Eight observers were used for this part of the test. They were seated before the box at such distances that the angular subtense of the window for the several observers ranged from about 4° to 6°.

Prior to the test, the observers were asked to set up for themselves a flicker-tolerance scale in five steps as follows:

None: No noticeable flicker.

Noticeable: Flicker present but small enough not to be bothersome.

Appreciable: An obtrusive amount of flicker, although tolerable, even for prolonged viewing.

Objectionable: An amount of flicker which would be intolerable for prolonged viewing.

Painful: An amount of flicker which is immediately intolerable.

The flicker box was adjusted to one of three levels of average brightness, 5, 10, or 20 foot-lamberts. The flicker box was set at random at some value of flicker frequency. The observers viewed the box for 10 seconds and were asked to assign a step value on the flicker-tolerance scale to this setting. The box was then turned off while judgments were recorded and the flicker box set for another flicker frequency. This procedure was repeated until the gamut of frequencies had been run and then the entire procedure was repeated for the other two brightness levels. The room in which the measurements were made was dark throughout.

The results of this test are given in figures 2, 3, and 4. Figure 2 gives the average tolerance scales for all eight observers at the three brightness levels. Figures 3 and 4 give the results of the measurements at 10- and-20-foot-lambert brightness levels for seven individual observers. (These seven were used also in the second part of the test in which the equivalent flicker of the color-television set was located on the scale.)

*B. CBS flicker tolerance*

The test to determine the tolerance-scale value of the flicker of the CBS color-television system was carried out on January 31, 1950, at the Walker Building, where CBS had set up several SKF receivers for a public demonstration. The flicker box was set up alongside an SKF receiver and the observers were seated in approximately the same relative positions they held for the flicker-tolerance scale test. Eight observers were used in this test, seven of whom participated in the tolerance-scale test also. The room was darkened during this test.

Tests were made on the four CBS test-pattern colors: Red, green, blue, and yellow. The transmission was set to fill the entire receiver screen with one selected color from the test pattern. The brightness level for each color was adjusted so as to obtain approximately the relative viewing conditions prevailing in good reception. The brightness values used were—

| | Foot-lamberts |
|---|---|
| Red | 10 |
| Blue | 10 |
| Green | 18 |
| Yellow | 17 |

After the brightness of the television screen had been adjusted, the brightness of the flicker box was adjusted to the same level with the flicker rate set above the critical frequency. The flicker box was not color-matched to the television screen. With the SKF receiver left undisturbed, the flicker frequency of the flicker box was set successively and at random at various values. At each setting, left on for about 5 seconds, the observers were asked to judge which flickered more, the flicker box or the television set. After the 5-second comparison period, the flicker box was turned off and the judgments recorded. This procedure was repeated for all four colors.

The value of flicker-box flicker frequency at which the observer's judgments reversed was considered to be the equivalent flicker frequency of the color-television set for that color at the set brightness

level. The equivalent flicker frequencies for the four colors are shown in figure 2 underneath the flicker-tolerance scale for the nearest brightness level. The results for seven individual observers are shown in figures 3 and 4.

### V. DISCUSSION

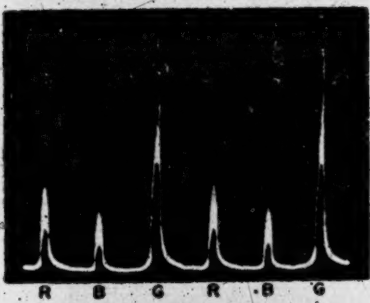
It may be seen in figure 2 that the flicker of the CBS television set was classed as "Noticeable" according to the flicker tolerance scale set-up. At the higher brightness, the flicker was near the "Appreciable" end of the "Noticeable" region. At the lower brightness, the flicker was near the critical frequency. The judgments as to the tolerance of flicker seem to be more affected by the brightness level than by the particular color viewed.

The conditions of this test were relatively severe. The use of a field of uniform color completely devoid of subject interest or variety and the direction of the attention of the observers to the specific subject of flicker undoubtedly gave what flicker there was more prominence than it would have for the ordinary television program viewer. It is therefore evident that the amount of flicker inherently present in the CBS color television system, while noticeable, is unobjectionable.

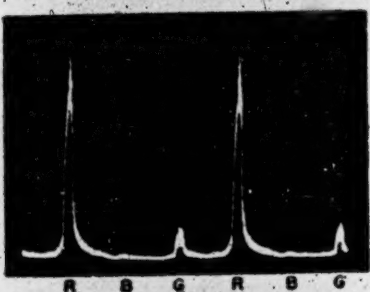
The assistance of Dr. D. B. Judd and Mr. C. A. Douglas of the National Bureau of Standards in these tests is gratefully acknowledged.

## COLOR TELEVISION TEST
## BRIGHTNESS VS. TIME CURVES
## CBS TEST PATTERN COLORS

Each record represents a sequence of six fields making a complete frame. The letters R, B, and G indicate red, blue, and green sequential fields. The field of view in these measurements was restricted to a square area with sides of length approximately 1/7 of screen width.

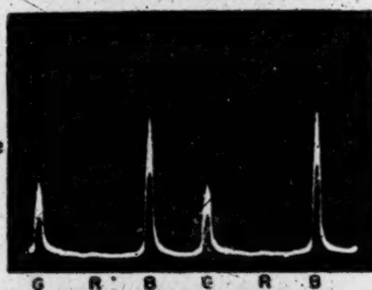


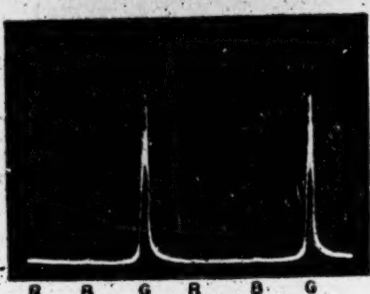

White




Red

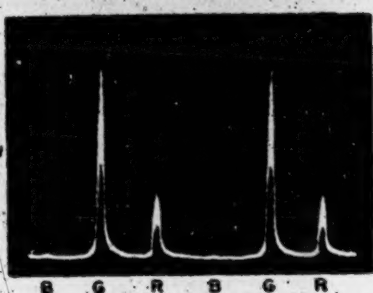
Blue



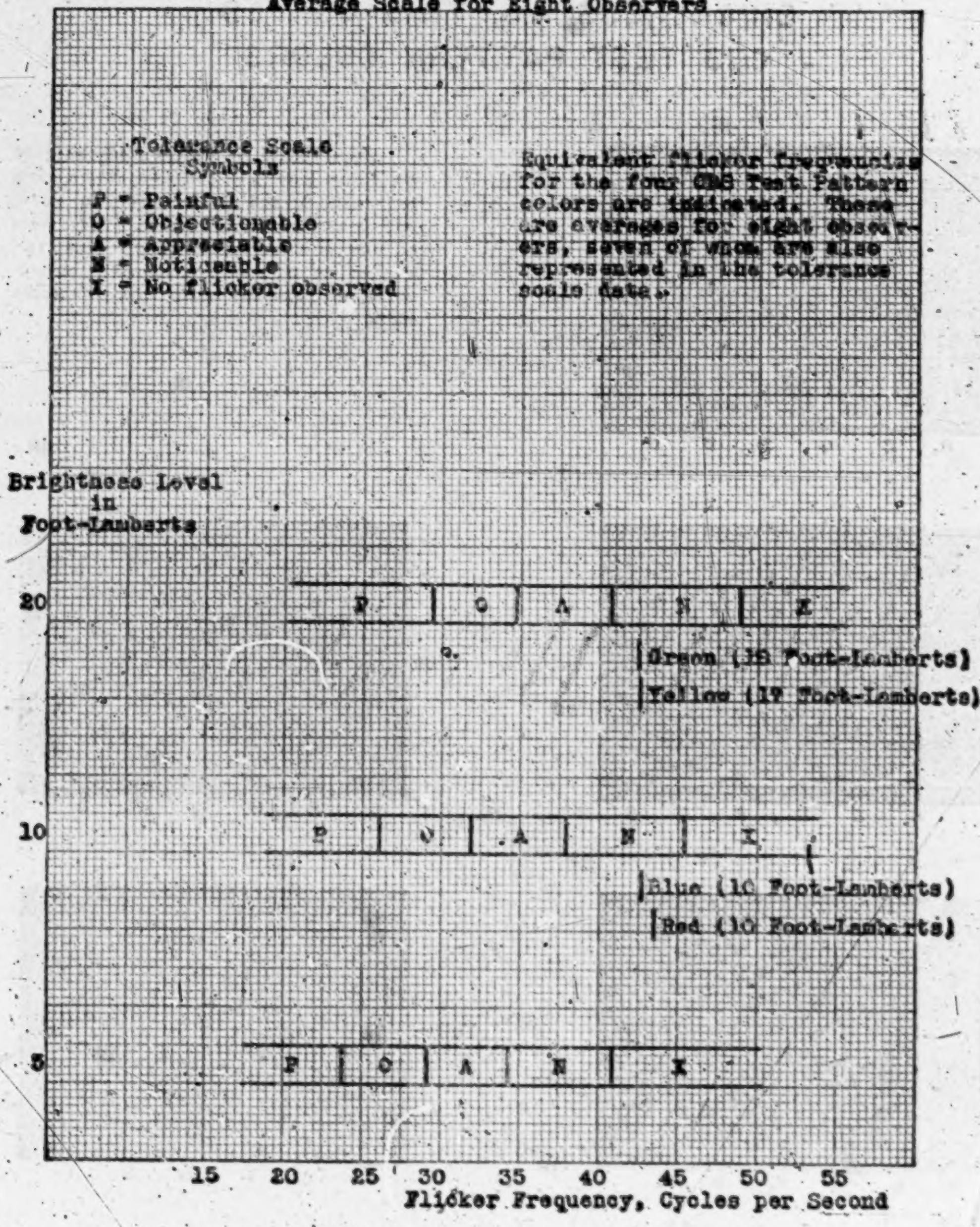




Green

Yellow



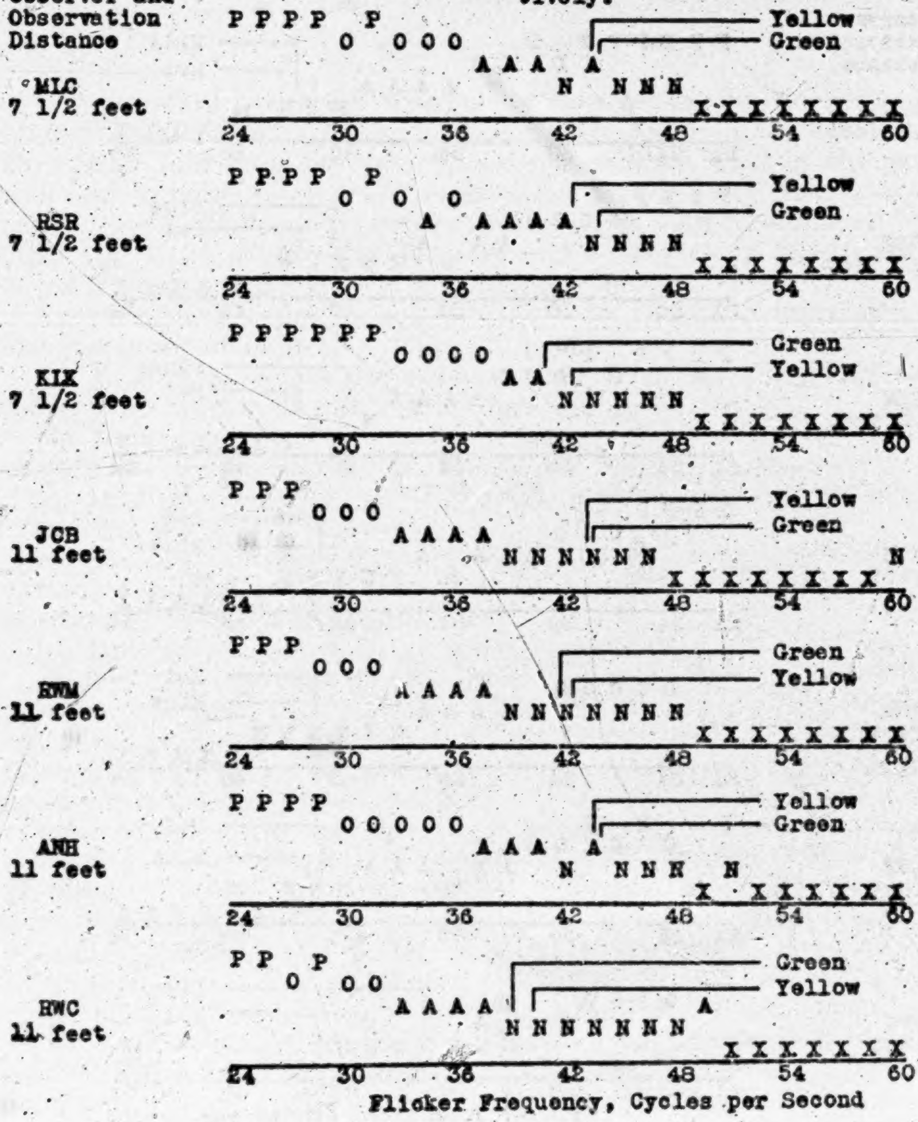
COLOR TELEVISION TEST
FLICKER TOLERANCE SCALE
Average Scale for Eight Observers



COLOR TELEVISION TEST
FLICKER TOLERANCE SCALE DATA
Brightness Level = 20 Foot-Lamberts

Tolerance Scale Symbols
P = Painful  O = Objectionable
A = Appreciable  N = Noticeable
X = No Flicker Observed

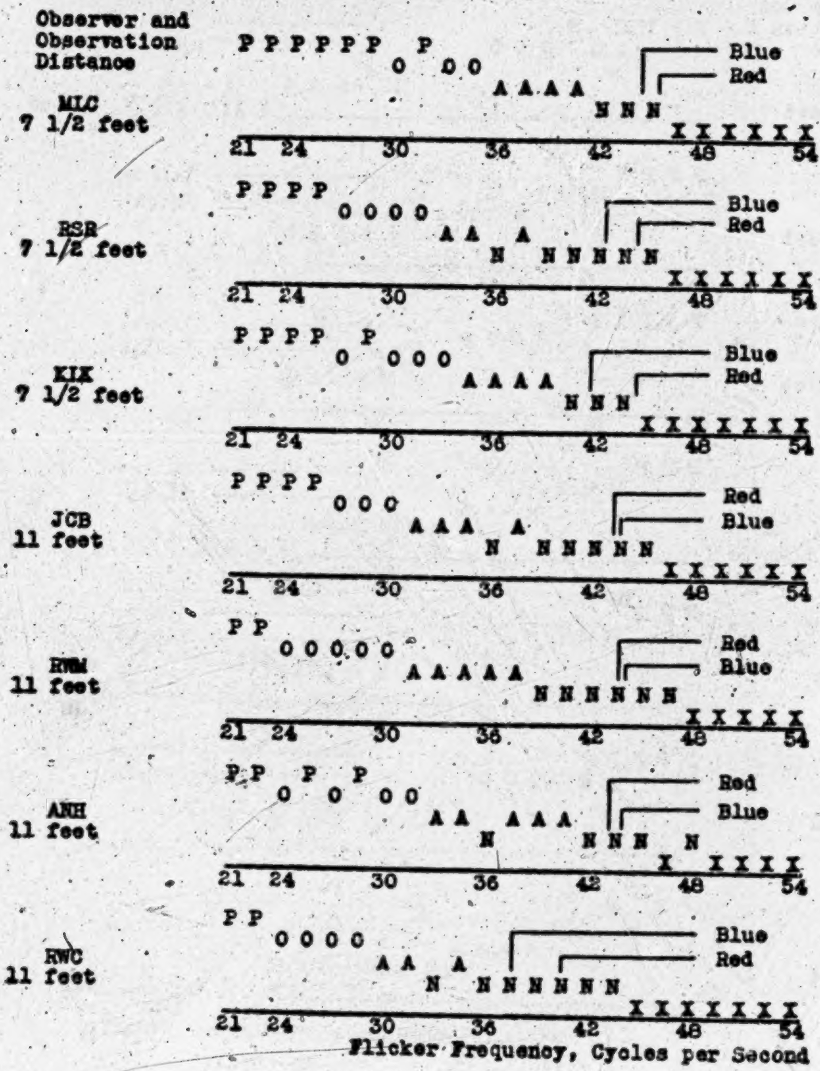
Equivalent flicker frequencies for two CBS Test Pattern colors are indicated. Brightness levels for green and yellow were 18 and 17 foot-lamberts, respectively.



COLOR TELEVISION TEST
FLICKER TOLERANCE SCALE DATA
Brightness Level = 10 Foot-Lamberts

Tolerance Scale Symbols
P = Painful O = Objectionable
A = Appreciable N = Noticeable
X = No Flicker Observed

Equivalent flicker frequencies for two CBS Test Pattern colors are indicated. Brightness level for both was 10 foot-lamberts.



# ANNEX E

## Report on the Fidelity of Color Reproduction by the CBS and RCA Systems

(By Deane B. Judd, L. Plaza, and M. M. Balcom, National Bureau of Standards)

### I. INTRODUCTION

The question has been raised as to how faithfully can present-day systems of television in color reproduce the colors of the actual scene. How does this color reproduction compare with that in the graphic arts and in color photography—systems that already have consumer acceptance? This report compares the color fidelity achieved by the CBS and RCA systems in January and February of 1950 with that of color photography by the Kodachrome process.

An unfaithful reproduction of color can result in television from various types of failure:

(*a*) Failure to equip the camera with filters giving it the proper spectral sensitivity to control the receiver primaries.

(*b*) Improper adjustment of the camera resulting in its failure to initiate the proper signals to control the receiver primaries.

(*c*) Improper adjustment of the transmitter resulting in failure to broadcast the proper signals.

(*d*) Failure of the proper signals to arrive at the receiver due to various forms of interference to propagation of radio waves, superposition of extraneous signals, etc.

(*e*) Improper adjustment of the receiver.

Perfect reproduction of the colors of the scene is theoretically possible provided those colors lie within the gamut of colors producible by additive combination of the receiver primaries. An unfaithful reproduction of color from the above causes is said to come from poor color control or poor color balance. This report indicates the degree of color balance achieved by certain transmitter-receiver combinations operating in January and February of 1950 on the CBS and RCA systems. It does not indicate the ultimate color fidelity possible with those transmitter-receiver combinations, nor that theoretically possible by means of the CBS and RCA systems of color television in color, nor does it seek to point out the particular link of the system responsible for specific instances of unfaithful color reproduction. It is not a measure of the bad effects of misregistration of images, color fringing, or color breakup. It is simply a record of the color fidelity achieved at certain times by the CBS and RCA systems of color television.

### II. METHOD

The method was to measure the colors of two test charts, each having four colors plus white; then to measure the rendition of these colors on the tube of the television receiver; then to compare the

relationship of these eight rendered colors to the rendered white with the relationship between the eight actual colors to the actual white.

(*a*) *Test charts.*—Each chart (18 by 24 inches) consisted of four colors covering the quadrants of a rectangle except for a central rectangle covered with white. Table 1 shows the Munsell notations of the nine colors, first estimated by visual comparison with the color scales in the Munsell Book of Color,[1] and second found by means of the colorimeter used to measure the colors produced by the television receivers.

(*b*) *Colorimeter.*—A special colorimeter for measuring the colors of self-luminous areas was assembled for this test. In this colorimeter one-half of the field of the Martens photometer was filled with light from the test area; the other half was filled with light from an incandescent lamp (standard illuminant A) filtered through a combination of Lovibond glasses (red, yellow, blue) adjustable in number of Lovibond units.[2] A double-cell liquid filter (Davis-Gibson)[3] converting illuminant A to illuminate C (representative of average daylight) could also be inserted. For each combination of filters and setting of the Martens photometer the luminance, Y, and chromaticity coordinates, x and y, are known by means of calibration graphs.

For each chart under illuminant C and for each rendition of each chart on the screen of the television receiver measurements were made of the luminance, $Y$, and chromaticity coordinates [4], $x$ and $y$, of the white area, and of the four test colors.

(*c*) *Reduction of data.*—From the measured values of $Y$, $x$ and $y$, for each area, the tristimulus values, $X$, $Y$, $Z$, were computed by the formulas:

$$\begin{aligned} X &= x(Y/y) \\ Y &= Y \\ Z &= z(Y/y) \end{aligned} \tag{1}$$

These tristimulus values, $X$, $Y$, $Z$, were then adjusted by constant factors so that the white area had the values $X'=0.847$, $Y'=0.864$, $Z'=1.020$, characteristic of a nonselective white surface of luminous reflectance, 0.864 illuminated by standard source C thus:

$$\begin{aligned} X' &= k_1 X \\ Y' &= k_2 Y \\ Z' &= k_3 Z \end{aligned} \tag{2}$$

where $k_1$, $k_2$, and $k_3$ are the factors constant for each rendition of each chart.

From the tristimulus values, $X'$, $Y'$, $Z'$, the adjusted chromaticity coordinates, $x'$ and $y'$, were computed:

$$\begin{aligned} x' &= X'/(X'+Y'+Z') \\ y' &= Y'/(X'+Y'+Z') \end{aligned} \tag{3}$$

From the values of $Y'$, $x'$, and $y'$, the Munsell renotations of the colors were read by interpolation on the graphs in the Final Report of the OSA Subcommittee on the Spacing of the Munsell Colors.[5]

[1] Munsell Book of Color, standard and pocket editions (Hoffman Bros., Baltimore, Md., 1929 and 1942). Available also through the Munsell Color Co., 10 East Franklin St., Baltimore Md.

[2] K. S. Gibson and F. K. Harris, The Lovibond color system, BS Sci. Paper No. 547 (1927).

[3] R. Davis and K. S. Gibson, Filters for the reproduction of sunlight and daylight and the determination of color temperature, Misc. Pub. BS, No. 114 (1931).

[4] D. B. Judd, The 1931 ICI standard observer and coordinate system for colorimetry, J. Opt. Soc. Amer. 23, 359 (1933).

[5] S. M. Newhall, D. Nickerson, and D. B. Judd. Final report of the OSA Subcommittee on the Spacing of the Munsell Colors, J. Opt. Soc. Amer. 33, 385 (1943).

In Munsell terms, the first symbol (such as 6R) indicates the Munsell hue, the second symbol (such as 5.0/) the Munsell value, and the third symbol (such as /10) the Munsell chroma, the whole notation being written 5R 5.0/10; see table 1. The Munsell system is useful for assessing the importance of the difference found between the actual colors and the rendition of the colors because of two properties: First, the Munsell scales have steps that are visually uniform; second, for usual observing conditions Munsell chroma correlates with the perceived departure of the color from gray; Munsell value correlates with the perceived lightness or darkness of the color; and Munsell hue correlates with the perceived hue. It has been found that unfaithful reproduction of hue is more objectionable to the public than much more easily perceptible discrepancies either in lightness or in saturation (departure from gray).

The final step therefore, is to find by subtraction the difference in Munsell hue between actual chart color and the rendered color, and the corresponding difference in Munsell value.

## III. TESTS MADE

At the request of the Senate Advisory Committee on Color Television the following tests were made:

*CBS system*

Three tests on an RCA receiver, 7-inch tube with color converter and lens, called the dual receiver at this Bureau, brightness and contrast controls adjusted by us to give as close a duplication of the test chart as possible. Test charts illuminated by 4,500° white fluorescent lamps in the studios of WTOP in the Warner Building.

Two tests on a Smith, Kline, and French medical receiver built by Zenith and located in the Walker Building, Washington, D. C. Receiver (called Zenith receiver) adjusted by CBS engineers to give what they considered to be the best possible picture. First test with transmitter adjusted to make the receiver rendition of the white area of the test chart color-match light from a daylight fluorescent lamp.

*RCA system*

One test on a large cabinet, three-tube receiver, and one test on a smaller so-called high-level three-tube receiver such as used at the Laurel demonstration before the Federal Communications Commission, both tests made at this Bureau. In both tests the receivers and the transmitter were adjusted for the best possible rendition of the test charts by RCA engineers. Test charts were illuminated by incandescent-lamp light in the studios of WNBW in the Wardman Park Hotel.

*Color photography by the Kodachrome system*

Photographs on stock 8- by 10-inch Kodachrome film were made of the two test charts at this Bureau by the Photographic Technology Section on February 6. The charts were illuminated by light from 4,500° white fluorescent lamps. One pair of pictures was underexposed, one was exposed for the time interval suited to the illumination, and one was overexposed. The film was sent to Eastman Kodak Co. for processing and on being returned was illuminated as a

transparency by standard illuminant C and the colors measured in the same way as those produced by the television receivers.

## IV. RESULTS

Table 2 shows the dates of the various tests, identifies the system of color television and the receiver tested, indicates the adjustment of the transmitter and the receiver, and gives the average discrepancy between test color and the rendition of it in terms of Munsell value, Munsell chroma, and Munsell hue. The average deviations in Munsell hue between test color and rendition have been multiplied by the chroma of the color (average of test chart and rendition), the perceptibility, and hence importance, of hue differences being proportional to chroma of the colors being compared.

## V. DISCUSSION

It will be noted from table 2 that the CBS and RCA systems of television in color in these instances gave consistently more faithful reproduction (smaller discrepancies, $\Delta V$) in Munsell value of the test colors than the Kodachrome system of color photography. The reverse is true for reproduction of hue, and there is little to choose between the systems in regard to reproduction of Munsell chroma of the test colors.

If an over-all evaluation of color fidelity taking into account all three kinds of color departure (Munsell hue, value, and chroma) is to be given, some estimate of the relative importance of the Munsell hue step, the Munsell value step, and the Munsell chroma step must be made. We believe that in color rendition one Munsell value step is about as important as two Munsell chroma steps or one Munsell hue step at chroma/10. We propose tentatively, therefore, the following index of color fidelity, $F$:

$$F = 100\,[1 - (\bar{C}\Delta H/5 + 2\Delta V + \Delta C)/30] \qquad (4)$$

The last column of table 2 gives values of color fidelity, $F$, computed from the averages of $\bar{C}\Delta H$, $\Delta V$, and $\Delta C$, from this formula. It will be noted that the color fidelity achieved by the CBS system in these tests is about the same as that achieved by the Kodachrome system of color photography, and that by the RCA system is not importantly worse.

## VI. CONCLUSIONS

(*a*) In January 1950 the CBS system of television in color was found to yield as faithful reproductions in color as is common by Kodachrome photographs. It was at that time sufficiently developed to give trouble-free operation at this level of color fidelity.

(*b*) In February 1950 the RCA system of television in color was found to yield substantially as faithful reproductions in color as is common by Kodachrome photographs. It was not shown at that time to be sufficiently developed to yield these results without constant expert attention to the receiver.

TABLE 1.—*Munsell book notations of the test colors*

[Illuminant: ICI standard *C*, representative of average daylight]

| Color | Munsell book notation: Visual comparison to Munsell book of color | Munsell book notation: Measured by colorimeter |
|---|---|---|
| Red | 5R 5.3/10 | 6R 5.4/8.8 |
| Yellow | 5Y 9.0/9.0 | 6Y 9.0/9.3 |
| Purple | 6P 4.2/9.5 | 5P 4.3/9.4 |
| Green | 4G 7.0/6.5 | 4G 7.2/8.3 |
| Flesh | 6YR 8.2/6.0 | 7YR 8.0/5.2 |
| Blue | 10B 5.3/8.0 | 1PB 5.5/7.6 |
| Neutral | N 6.7/ | 8G 6.8/0.4 |
| Foliage green | 5GY 5.4/4.5 | 6GY 5.8/4.6 |

TABLE 2.—*Discrepancies in Munsell value, chroma, and hue between test color and rendition of it, also numerical evaluation of over-all color fidelity*

| System | Date 1950 | Receiver | Transmitter operation | Receiver adjustment | Average discrepancy between test color and rendition of it: $\Delta V$ | $\Delta C$ | $\bar{C}\Delta H$ | Color fidelity, $F$ |
|---|---|---|---|---|---|---|---|---|
| CBS | Jan. 18: 10:15 | Dual | Normal | By NBS to give best match for charts. | 1.15 | 2.44 | 17.6 | 72 |
| | 11:45 | do | do | | .90 | 1.59 | 24.5 | 72 |
| | Jan. 25 | do | do | | .59 | 2.56 | 25.2 | 71 |
| | Jan. 26 | Zenith | do | By CBS to give normal operation. | 1.36 | 2.31 | 18.9 | 71 |
| | do | do | White to match daylight. | | 1.50 | 2.94 | 31.9 | 59 |
| RCA | Feb. 24 | Cabinet | Normal | By RCA to give best match for charts. | .64 | 1.72 | 41.2 | 63 |
| | Mar. 2 | High level | do | | .97 | 3.64 | 34.1 | 59 |
| | | Exposure | | | | | | |
| Kodachrome | Feb. 6 | Under | | | 2.26 | 2.32 | 20.5 | 64 |
| | do | Correct | | | 2.14 | 2.31 | 14.1 | 69 |
| | do | Over | | | 2.25 | 2.32 | 18.6 | 65 |

[fol. 423] ANNEX D

Radio Corporation of America

RCA Laboratories Division

Princeton, N. J.

C. B. Jolliffe

Executive Vice President

In Charge of

RCA Laboratories Division

July 31, 1950.

Honorable T. J. Slowie, Secretary, Federal Communications Commission, Washington 25, D. C.

DEAR SIR:

There are enclosed 20 copies of "Progress Report of RCA on Color Television and UHF" which was prepared for the information of the radio industry. It is expected that additional reports of this kind will be distributed from time to time. As they are issued, copies will be sent to the Commission for the information of the members and its staff.

If members of the Commission or its staff are interested in obtaining further information on the work referred to in this progress report, I will be glad to furnish it or arrange visits for them to see the work and discuss the results with RCA engineers.

I request that you kindly supply a copy of this report to each member of the Commission.

Very truly yours,

(Signed) C. B. Jolliffe.

[fol. 424] Progress Report of RCA on Color Television and UHF

July 31, 1950

During the hearing on color television (Docket 8736 et al.) RCA through testimony and bulletins kept the Commission and industry informed of the progress of development of the RCA color television system. RCA also indi-

cated that work on certain aspects of the system and its components was continuing. Since the close of the hearing, there has been further substantial progress in various phases of this work, and RCA now presents a report to the industry on these developments.

## (A) Tri-Color Tubes

Research work on the RCA tri-color tubes has now progressed to the point where RCA color system receivers utilizing these tubes produce pictures with a highlight brightness of more than 20 ft.-lamberts, with resolution capabilities comparable to those provided by the 6-megacycle television channel, and with dot structure and moire pattern substantially eliminated.

The increase in brightness is due to two factors: (1) the development of an improved red phosphor of proper chromaticity, making it possible to remove the red filter from in front of the tube which increases light output by 2 to 1; and (2) the use of improved tube techniques which give a higher light output, using the same applied voltages as used in the demonstrations in March-April 1950. The increase in resolution is due to the use of color screens which now have approximately 600,000 phosphor dots instead of 351,000 as in the original screens. The elimination of dot structure and moire pattern is due to the use of improved circuits in the receivers which make better use of by-passed "mixed highs".

[fol. 425] Additional research work on the tri-color tube is directed toward a further increase in resolution capabilities, increased brightness, and the construction of shorter tubes. As previously indicated, work on increased tri-color tube resolution will be continued until the number of phosphor dots is sufficient so that the tube resolution capabilities will be substantially in excess of that afforded by the 6-megacycle channel. Results of research work on guns, screens and masks for tri-color tubes indicate that before long there can be a further improvement in brightness of at least 2 to 1 (i.e., of the order of 40-50 ft.-lamberts). The progress thus far in work with larger deflection angles and improved guns makes it appear feasible to construct tri-color tubes of approximately the same length as ordinary black and white kinescopes. Work on the above items, applied both to three-gun and single-gun tubes, is continuing.

Of the substantial number of tri-color tubes thus far made by RCA Victor Division, the majority are being used or are assigned for use in the color receiver program (see (B) below) and the remainder are being used for study, tests and experimental work. It is hoped that the supply of tubes will be such that samples can be made available to the industry in the fall for their own study and development work.

The construction and test of the tri-color tubes to date have given RCA experience that will make it possible to continue to improve the tubes and to adapt them to mass production. RCA Victor Division is continuing its studies and tests along these lines and is working toward pilot line production by January, 1951.

(B) Color Receivers

Receiver circuits have been developed which are simpler and more stable in operation than those used in receivers demonstrated in March-April, 1950. They also make more effective use of the by-passed "mixed highs" principle. [fol. 426] Receivers incorporating these circuits and the latest model tri-color kinescope produce a color picture that has substantially the same resolution and is as stable as the picture produced on a standard monochrome receiver. The operating controls are the same as for black-and-white operation. A maximum of eight tubes and possibly only six, is added to the video circuits of a standard monochrome receiver to produce the color picture. It is, of course, necessary to provide the appropriate power supply and convergence circuitry to obtain proper operation of the tri-color tube. Field test receivers incorporating this design are being constructed and will be available for testing in the Washington area by the end of August.

Other development models of color receivers using the tri-color tube are now being tested in the Washington area. Thirteen receivers have been constructed or are under construction at RCA Laboratories. These receivers, which have various types of circuits, will be used to test operating characteristics to determine the best circuits for pilot line production and to develop information relevant to the manufacture of color receivers.

As originally indicated by General Sarnoff, RCA Victor Division is building tri-color tube receivers in Camden and

expects to have 35 receivers completed by September, with a schedule thereafter for pilot line assembly of five receivers per week.

The color receivers thus being made available will be used to fulfill RCA's testing requirements, to make receivers available to other manufacturers for their own use and investigations and to permit field test installations in homes in the Washington area.

For the immediate future, the color receivers referred to above will use three-gun tri-color tubes of the type previously demonstrated, but with at least a 100% increase in brightness. However, as soon as RCA tri-color tubes with the higher resolution and the new phosphors are available in quantity, they will be used in the receiver program. [fol. 427] Work is also progressing on receivers utilizing the single-gun tri-color kinescope. These receivers now include means for adjusting color balance at the receiver so that the picture produced is comparable with that obtained on receivers using three-gun kinescopes.

## (C) Color Studio Equipment

As was previously indicated, RCA is prepared to take orders for studio equipment for experimental use with the RCA color system. At the present time, four complete camera chains are under construction for use within RCA. In addition, orders for 10 flying spot scanning equipments for experimental purposes have been received and the equipments are under construction—two for development laboratories of manufacturers other than RCA and the remainder for laboratories of RCA Divisions and Companies. Inquiries have been received from other manufacturers relative to the purchase of RCA color studio equipment for experimental purposes.

Improved transmitter sampling techniques have been developed. Also, work is in progress on several types of studio and field cameras, including improvements on cameras of the type now in use at WNBW. These improved cameras (which include a camera using a single-image orthicon) use simpler circuits and make more effective use of the "mixed highs" principle. The different cameras are in various stages of development. Testing will be done in the studio of WNBW, Washington, D. C., as the various cameras reach that development stage. It is ex-

pected that at least one of the new cameras will be in operational test in Washington in September, 1950.

New studio cameras are also being built in the model shop at the Princeton laboratories to replace those now in Washington. The new cameras incorporate improved circuits and more nearly approach commercial-type design.

[fol. 428] (D) Equipment for Coaxial Cable Color Transmission

At the present time improved equipment for 2.4 mc. sampling is being installed in Washington for further field test and refinement of color transmission over existing coaxial cable circuits. This equipment will provide, on both color and monochrome receivers, pictures with resolution substantially equivalent to the standard monochrome picture from standard studio equipment when transmitted over 2.7 mc. coaxial cable.

(E) Color Broadcasting

The regular schedule of color broadcasting has continued over WNBW in Washington without interruption. As of July 31, 1950, WNBW has transmitted a total of 1,250 hours of color programs and test patterns. A substantial part of this has been "live" programs produced by the regular program and studio staff of NBC-Washington. All operations are by NBC's regular television personnel. A color consultant has also been engaged to assist in the development of color programming techniques. The experimental UHF station in Washington, KG2XCL, has transmitted 847 hours of color programs and test patterns.

The present color program schedule in Washington consists of 7 hours of studio programs per week, Monday through Friday, and approximately 25 hours per week of color test patterns. Commencing in the fall, this schedule will be extended to include studio programs on Saturday and Sunday as well. To prepare for expansion of the color broadcasting schedule, NBC is proceeding with the training of additional personnel and is equipping additional space for WNBW at the Wardman Park Hotel.

[fol. 429] (F) Oscillator Radiation

RCA is on record by a letter of Mr. Frank M. Folsom, its President, that the problem of oscillator radiation should

be dealt with as a matter of receiver design. RCA has been concerned with and has investigated the problem of receiver oscillator radiation for a number of years and has devised improved circuits to reduce this radiation. For example, in the television receivers announced in July, 1950, RCA has already taken further steps to achieve substantial reduction in oscillator radiation. Further improvements will be made, if possible, in future designs.

As in the past, RCA will circulate to the industry a description of the methods used by RCA in the reduction of oscillator radiation, and the RCA Industry Service Laboratory will continue to assist receiver manufacturers in their attack on the problem.

RCA engineers will continue to work closely with the RTMA and IRE committees. Much assistance and data have already been furnished, particularly with regard to proper and accurate measurement techniques and the standards therefor.

The setup of open field test facilities at RCA Laboratories in Princeton, N. J., for the measurement of oscillator and other receiver radiation has been completed and placed in operation. Already 20 receivers from 10 different manufacturers have been measured and more receivers are coming in daily for measurements. It is felt that these facilities and experience gained in their use will be of benefit to the television industry in the evolution of designs which will conform to appropriate standards and will result in substantial reduction in oscillator and other receiver radiation.

[fol. 430] (G) UHF Bridgeport

The operation of NBC's experimental UHF television station, KC2XAK, Bridgeport, Connecticut, is continuing on a regular schedule, Tuesday through Saturday, from approximately 9:00 A. M. until WNBT signs off at night. These transmissions consist of the reproduction of WNBT's regular scheduled programs and test transmissions. As of July 31, 1950, KC2XAK has operated a total of 2,075 hours.

Over 250 industry representatives, broadcasters, engineers, and others have visited KC2XAK since it has been in operation. They have had opportunity to familiarize themselves with the installation and with the problem of UHF operation in the Bridgeport area. Several receiver

manufacturers have tested development designs of UHF receivers in this area.

The field strength survey in the Bridgeport area has been completed to the point where available data is being analyzed to determine what further measurements are required. Necessary additional data will be taken.

Over 75 UHF receivers and converters have been installed in homes and other locations in the Bridgeport area which have provided information on UHF installation and antenna problems and have given a measure of actual home television performance in the UHF band.

Recordings of the signals from Bridgeport have been made on the roof of the RCA Building in New York (line-of-sight). These recordings, running over three months, have shown very constant signal strength and have produced little new information. Accordingly, the equipment has now been moved to Lynbrook, L. I., for further recordings at a location below line-of-sight and within the 50-mile area of the station.

Recordings have also been made at Riverhead, L. I. for the last six months and at Princeton, N. J. for three months. These show considerable variation in signal [fol. 431] strength and it is planned to continue them through a full year's cycle to obtain information on daily and seasonal variations in signal intensity due to tropospheric effects and other varying conditions of the signal path.

The results of these surveys and recordings are being analyzed and will be included in the regular reports made by NBC in accordance with the requirements of its experimental license. These reports will be circulated to interested parties and presented to the FCC at the time of the allocations hearing.

* * * * * * *

On October 20, 1949, RCA commenced the distribution to the Commission and to the industry of bulletins covering various aspects of its work on color and UHF television. To date fifteen of these bulletins have been distributed, the last two since the close of the hearing. The list of the titles and exhibit numbers of these bulletins is attached.

[fol. 432]

RCA Bulletins on Color Television and UHF

| Date | Title | Exhibit Number |
|---|---|---|
| 10/20/49 | A 15 by 20-Inch Projection Receiver for the RCA Color Television System | 305 |
| 10/31/49 | Synchronization for Color Dot Interlace in the RCA Color Television System | 306 |
| 11/ 9/49 | A Two-Color Direct-View Receiver for the RCA Color Television System | 307 |
| 12/12/49 | An Experimental UHF Television Tuner | 308 |
| 1/ 9/50 | A Three-Color Direct-View Receiver for the RCA Color Television System | 309 |
| 1/17/50 | An Experimental Determination of the Sideband Distribution in the RCA Color Television System | 310 |
| 1/17/50 | A Study of Co-Channel and Adjacent Channel Interference of Television Signals, Part I | 311 |
| 1/30/50 | A Study of Co-Channel and Adjacent Channel Interference of Television Signals, Part II | 312 |
| 1/30/50 | An Experimental UHF Television Converter | 313 |
| 2/ 8/50 | Recent Developments in Color Synchronization in the RCA Color Television System | 314 |
| 2/15/50 | Colorimetric Analysis of RCA Color Television System | 315 |
| 2/28/50 | A Simplified Receiver for the RCA Color Television System | 316 |
| 4/17/50 | General Description of Receivers for the RCA Color Television System Which Employ the RCA Direct-View Tri-Color Kinescopes | (Material originally submitted as Exhibit No. 382) |
| 7/28/50 | Analysis of the Sampling Principles of the RCA Color Television System | (Material originally submitted in part as Exhibit No. 379 |
| 7/28/50 | Mixed Highs in Simultaneous Color Television | |

[fol. 433]

ANNEX E

Federal Communications Commission

Washington 25, D. C.

May 3, 1950.

Radio Corporation of America, 30 Rockefeller Plaza, New York 20, N. Y.

Gentlemen:

The Commission has announced a television demonstration by CTI to be held in San Francisco, California, on May 17, 1950.

The Commission desires to view a color picture transmitted by the proposed CTI system with relative high

brightness and on a direct viewing device. CTI does not have such a device and the Commission feels that it would be helpful if you could make available to CTI for their use in the above demonstration a direct view receiving device with dichoric [sic] mirrors similar to that used in receivers demonstrated recently by your company.

Very truly yours, (S) T. J. Slowie, Secretary.

CC:

Mr. Joseph Heffernan
Color Television Incorporated
Wheat, May & Shannon

[fol. 434] Affidavit of Service

STATE OF NEW YORK
County of New York, ss.:

ANNE DUBIVSKY, being first duly sworn, upon oath deposes and says:

That she has this day served a copy of the foregoing Comments of Radio Corporation of America upon each of the parties of record in the color part of the proceedings in Docket Nos. 8736, 8975, 9175 and 8976, at the addresses shown below, by regular or air mail, postage prepaid:

Mr. Donald Fink, Joint Technical Advisory Committee, 1 East 79th Street, New York, N. Y.

Burton Wheeler, Esq., Southern Building, Washington, D. C.

Rosenman, Goldmark, Colin & Kaye, 165 Broadway, New York, N. Y.

Lippincott & Smith, 24 California Street, San Francisco 11, California.

Dr. Charles Willard Geer, University of Southern California, Los Angeles, California.

George S. Elpern, Esq., 1017 Woodward Building, Washington, D. C.

Henry B. Weaver, Esq., Tower Building, Washington, D. C.

[fols. 435-436] Roberts & McInnis, Mayflower Office Building, Washington, D. C.

Mr. C. P. Cushway, Webster-Chicago Corporation, 5610 West Bloomingdale Street, Chicago, Illinois.

R. Harvey Levinson, Esq., 33 North La Salle Street, Chicago, Illinois.

Arnold, Fortas & Porter, 1200—18th Street, N. W., Washington, D. C.

(S) Anne Dubivsky

Subscribed and sworn to before me this 28th day of September, 1950, (S) Marjorie E. Vetter, Notary Public, State of New York, No. 31-9462200, Qualified in New York County, Cert. filed with New York Reg. Offices, Term expires March 30, 1952.

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[fol. 437] Exhibit "E" to Complaint

Before the Federal Communications Commission

Washington, D. C.

In the Matters of

Docket Nos. 8736 and 8975

Amendment of Section 3.606 of the Commission's Rules and Regulations.

Docket No. 9175

Amendment of the Commission's Rules, Regulations and Engineering Standards Concerning the Television Broadcast Service.

Docket No. 8976

Utilization of Frequencies in the Band 470 to 890 Mcs. for Television Broadcasting.

## Petition of RCA

RCA petitions the Commission:

(a) during the period December 5, 1950 to January 5, 1951, to review the improvements made in the performance of the RCA system; and

(b) during the period to June 30, 1951, to view experimental broadcasts of color signals under the RCA, CBS, CTI and other systems, before making a final determination in respect of color standards.

In its Second Notice of Further Proposed Rule Making, released September 1, the Commission requested that by [fol. 438] September 29 all manufacturers of television receivers submit comments in respect of "bracket standards".

We have reviewed the comments filed in accordance with such request. It seems clear from these that it is not practical to manufacture bracket standard receivers within the time prescribed by the Commission.

Since the majority of the Commission felt the most desirable course was to allow more time for the development of all color systems, subject only to a condition which has now been shown to be impractical, we submit the Commission should now allow that time.

We suggest that both the December 5 to January 5 period, referred to by the majority, and the June 30 date, referred to by Commissioner Hennock, be adopted.

During the period December 5 to January 5 we will show the Commission the improvements made in the performance of the RCA system, with particular reference to those points about which the Commission expressed doubts. Some of those improvements are set forth in the RCA Progress Report of July 31, 1950.

By June 30 we will show that the laboratory apparatus which RCA has heretofore demonstrated has been brought to fruition in a commercial, fully-compatible, all-electronic, high-definition system of color television available for immediate adoption of final standards.

Respectfully submitted, Radio Corporation of America, C. B. Jolliffe, Executive Vice President, in Charge of RCA Laboratories Division.

October 4, 1950.

[fol. 439] EXHIBIT "F" TO COMPLAINT

55702
FCC 50-1227

Federal Communications Commission

Washington, D. C.

In the Matters of

Docket Nos. 8736 and 8975

Amendment of Section 3.606 of the Commission's Rules and Regulations

Docket No. 9175

Amendment of the Commission's Rules, Regulations and Engineering Standards Concerning the Television Broadcast Service.

Docket No. 8976

Utilization of Frequencies in the Band 470 to 890 Mcs. for Television Broadcasting

Order

At a session of the Federal Communications Commission held at its offices in Washington, D. C., on the 10th day of October, 1950;

The Commission having under consideration a petition filed on October 4, 1950, by Radio Corporation of America (RCA), requesting (1) that during the period December 5, 1950 to January 5, 1951, the Commission review the improvements made in the performance of the RCA system, and (2) that during the period to June 30, 1951, the Com-
[fol. 440] mission view experimental broadcasts of color signals under the RCA, CBS, CTI and other systems before making a final determination with respect to color standards; and

It appearing that the hearing herein on the issues relating to the adoption of rules, regulations and standards for color television was conducted by the Commission during the period commencing September 26, 1949, and ending May 26, 1950; that said hearing consumed 62 days of testimony totalling 9,717 transcript pages; that the Commission heard the testimony of 53 witnesses and received in evi-

dence 265 exhibits; that demonstrations of proposed color television systems were viewed by the Commission on 8 separate occasions; that included among said demonstrations were those conducted by RCA at the Wardman Park Hotel in Washington, D. C., on October 10, 1949, at Temporary "E" Building in Washington, D. C., on November 21 and 22, 1949, at the Commission's Laboratories near Laurel, Maryland on February 23, 1950, and at the Trans-Lux Building in Washington, D. C., on April 6, 1950; and that the Commission studied and considered comprehensive and detailed proposed findings and conclusions and replies thereto filed between the date of closing of the above record and July 10, 1950; and

It further appearing that on September 1, 1950, the Commission issued its "First Report of Commission (Color Television Issues)" (FCC 50-1064), setting forth its findings and conclusions with respect to the color television issues herein and specifying the contingencies, terms and conditions under which it would give consideration to new proposed color television systems, and under which it might consider reopening the above hearing record; and

[fol. 441] It further appearing that petitioner has had a full and fair opportunity to present its proposals to the Commission; that the state of the television art is such that new ideas and new inventions are matters of weekly, even daily occurrence; that the question of approving a color television system which will best serve the interests of the American people is one which has been before the Commission for almost 10 years; that in all proceedings such as the instant one a point is reached which calls for administrative finality with respect to the Commission's hearing processes; and that in the sound discretion of the Commission a delay in reaching a determination with respect to the adoption of standards for color television service as requested in the instant petition would not be conducive to the orderly and expeditious dispatch of the Commission's business and would not best serve the ends of justice; and

It further appearing that simultaneously with the issuance of this Order the Commission is issuing its "Second Report of the Commission" (FCC 50-1224) and its "Order" amending its "Standards of Good Engineering Practice Concerning Television Broadcast Stations" (FCC 50-1225); and

It further appearing that the Commisison, in said "Second Report" stated:

"It is, therefore, contemplated that interested persons may conduct experimentation in accordance with experimental rules not only as to color television but as to all phases of television broadcasting. Of course, any person conducting such experimentation should realize that any new color system that is developed for utilization on regular television channels must meet [fol. 442] the minimum criteria for a color television system set forth in our First Report. In addition, any such system that is developed or any improvement that results from the experimentation might face the problem of being incompatible with the present monochrome system or the color system we are adopting today. In that event, the new color system or other improvement will have to sustain the burden of showing that the improvement which results in substantial enough to be worth while when compared to the amount of dislocation involved to receivers then in the hands of the public."

It is ordered that the petition herein is denied.

Federal Communications Commission.* T. J. Slowie, Secretary.

Released: October 11, 1950.

* Commissioners Sterling and Hennock concur in the result.

[fol. 443] EXHIBIT "G" TO COMPLAINT

55725
FCC 50-1224

Federal Communications Commission

Washington 25, D. C.

In the Matters of

Docket Nos. 8736 and 8975

Amendment of Section 3.606 of the Commission's Rules and Regulations

Docket No. 9175

Amendment of the Commission's Rules, Regulations and Engineering Standards Concerning the Television Broadcast Service

Docket No. 8976

Utilization of Frequencies in the Band 470 to 890 Mcs. for Television Broadcasting

Second Report of the Commission

1. On September 1, 1950, the Commission issued its First Report in the above-entitled proceedings. This Report contained detailed findings and conclusions concerning the three color systems which were proposed to the Commission on the record in these proceedings. The Report also set forth minimum criteria which a color system must meet in order to be considered eligible for adoption.

2. In brief, the Commission found that the so-called compatible systems proposed by Color Television, Inc. (CTI) [fol. 444] and Radio Corporation of America (RCA) in these proceedings fall short of the minimum criteria we have established for a color television system. As to the CTI system, the Commission found it deficient in the following respects:

(a) The quality of the color picture is not satisfactory.

(b) There is serious degradation in quality of the black and white pictures which existing receivers get from CTI color transmissions.

(c) The equipment utilized by the CTI system both at the receiver and station end is unduly complex.

(d) Insufficient evidence was offered as to whether the system is not unduly susceptible to interference.

3. The Commission found the RCA system deficient in the following respects:

(a) The color fidelity of the RCA picture is not satisfactory.

(b) The texture of the color picture is not satisfactory.

(c) The receiving equipment utilized by the RCA system is exceedingly complex.

(d) The equipment utilized at the station is exceedingly complex.

(e) The RCA color system is much more susceptible to certain kinds of interference than the present monochrome system or the CBS system.

(f) There is not adequate assurance in the record that RCA color pictures can be transmitted over the 2.7 megacycle coaxial cable facilities.

[fol. 445] (g) The RCA system has not met the requirements of successful field testing.

4. The Commission pointed out in its Report that if a satisfactory compatible color system were available, it would certainly be desirable to adopt such a system. However, the Commission was forced to conclude from the evidence in the record that no satisfactory compatible system was demonstrated in these proceedings and the Commission stated that in its opinion, based upon a study of the history of color development over the past ten years, from a technical point of view, compatibility, as represented by all compatible color systems which have been demonstrated to date, is too high a price to put on color. In an effort to make these systems compatible, the result has been either an unsatisfactory system from the standpoint of color picture quality, or a complex system, or both.

5. The Report stated that in the Commission's opinion, the CBS system produces a color picture that is most satisfactory from the point of view of texture, color fidelity and contrast. The Commission stated that receivers and station equipment are simple to operate and that receivers

when produced on a mass marketing basis should be within the economic reach of the great mass of purchasing public. The Commission further found that even with present equipment the CBS system can produce color pictures of sufficient brightness without objectionable flicker to be adequate for home use and that the evidence concerning long persistence phosphors shows that there is a specific method available for still further increasing brightness with no objectionable flicker. Finally, the Commission pointed out that while the CBS system has less geometric resolution than the present monochrome system the addition of color to the picture more than outweighs the loss in geometric resolution so far as apparent definition is concerned.

[fol. 446] 6. The Commission did not in its First Report finally adopt the CBS color system. Instead, it set forth a procedure whereby, if the status quo on compatibility were maintained, a decision would be postponed so that the Commission could give further consideration to four matters—large-size direct-view tubes on the CBS system, horizontal interlace, long persistence phosphors, and the development of new compatible systems and improvements in existing compatible systems, which had been informally called to the Commission's attention since the conclusion of the hearing. It is obvious that some procedure had to be devised whereby the compatibility problem would not be aggravated if a decision were postponed. Otherwise, we would be in the position of inviting the risk that if, after postponing a decision, the compatible color systems should again fail to meet the minimum criteria for a color system, as they have failed in the past, the number of receivers in the hands of the public would have increased to such a point where, as a practical matter, it might not be practicable to adopt an incompatible color system even though we now know that such system meets all of the criteria for a color system. Hence, it is obvious that if a decision were to be postponed, a method had to be devised to maintain the status quo on compatibility so that when the time did arrive for making a decision, the Commission would be in relatively the same position as it is today—so far as compatibility is concerned—to adopt a successful incompatible system if all of the compatible systems again failed to meet the minimum criteria for a color system.

7. The Commission's First Report suggested a method whereby the status quo on compatibility could be maintained. This method is the incorporation of brackets into receivers hereafter manufactured which would permit such [fol. 447] receivers to receive black and white pictures from present transmissions, CBS color transmissions and any other transmissions within a range of 15,000 to 32,000 lines per second and 50 to 150 fields per second. Manufacturers were requested to submit their comments by September 29, 1950 as to whether they could and would manufacture their receivers with such brackets commencing with the effective date of the Commission's order adopting the bracket standards as final.

8. The comments have now been received and have been carefully considered by the Commission. The manufacturers who have responded—and these manufacturers represent the greatest part of the manufacturing capacity of the television industry—have indicated that they are unable or unwilling to meet the requirements as to brackets set forth in the Commission's First Report and in its Notice concerning brackets. Nor have these manufacturers suggested any other method whereby the status quo as to compatibility can be maintained if a decision is postponed at the present time. Accordingly, we would be derelict in our responsibility to the public if we postponed a decision any longer. With no way of preventing the growth of incompatibility, the longer we wait before arriving at a final decision the greater the number of receivers in the hands of the public that will have to be adapted or converted if at a later date the CBS color system is adopted. Simultaneously with the release of this Report we are issuing an Order adopting standards for color television on the field sequential system. In view of the nature of the comments as to bracket standards, we are not able to adopt them without a hearing. Such a hearing will be scheduled at a later date.

[fol. 448] 9. In arriving at this conclusion we have carefully considered all the material set forth in the comments, filed pursuant to our notice concerning bracket standards, as they are directed to the findings and conclusions in the Commission's First Report relating to the three color systems. Most of this material is merely a restatement of the parties' contentions made over and over again during the

course of the hearing. These contentions have been analyzed in detail in the Report and no further discussion of them is necessary here.

10. There are, however, two contentions raised in the comments which merit a brief discussion. The first contention refers to the statement in paragraph 125 of the First Report that there is some doubt as to whether some of the color systems proposed in these proceedings meet the test of adaptability and convertibility set forth in the Commission's Notice of July 11, 1949. The argument is made that this statement refers to the CBS system and hence that it is not eligible for consideration. This contention is a distortion of the Commission's Report. It is clear from a reading of the Commission's Report that the CBS system squarely meets the test of adaptability and convertibility set forth in the Notice of July 11, 1949. It is the CTI and RCA systems that fail to meet the test, for neither CTI nor RCA demonstrated a practical converter and hence failed to meet the test of convertibility. However, the Commission did not rule out the CTI or RCA systems on this ground but instead considered both systems on the merits.

11. The second contention is that the Commission cannot on this record issue a final order at the present time but is limited to the issuance of proposed rules only. This [fol. 449] contention has no basis in fact. The Commission's Notice of July 11, 1949, proposed that the present transmission standards be utilized on Channels 2 through 55. Interested persons were explicitly invited to submit proposals for a change in transmission standards on these channels looking towards color television. These proposals were required to be specific as to any change or changes in the transmission standards proposed and had to meet certain requirements. Pursuant to this Notice, CTI, CBS and RCA submitted specific color proposals. Evidence in support of and in opposition to these specific proposals was offered during the hearing. The standards which are being adopted by the Commission are the result of expert calculations based upon the characteristics of the present standards and the evidence concerning the CBS field sequential color system. It is clearly within the province of the rule-making proceedings as prescribed by the Adminis-

trative Procedure Act to adopt such standards without the necessity for further proceedings.

12. In arriving at our conclusions in this Record, we have not overlooked the matters set forth in paragraph 6 of this Report as to which we indicated we would give further consideration if a decision were postponed. The first such matter is the problem of large-size direct-view tubes in the CBS system. As we pointed out in our First Report, at the present time the CBS system is, as a practical matter, limited to direct-view tubes no larger than 12½ inches in size. However, we are willing to adopt the CBS system on the basis of the evidence in the record which satisfied us that CBS can produce satisfactory color pictures on projection receivers and on direct-view tubes of at least 12½ inches in size. The argument is made that the trend in purchasing has been to larger size direct-view [fol. 450] receivers and hence the public will not buy projection receivers or direct-view receivers with a 12½ inch tube. This may be true when all sets receive black and white pictures only. However, the Commission believes that the attractiveness of color pictures may be sufficiently great to cause people to prefer a direct-view receiver with a 12½ inch tube or a larger size projection receiver if they can get color as against a 16 inch, 19 inch or larger direct-view receiver that is limited to black and white pictures. In any event, if both types of receivers are offered to the public, it will be the free forces of competition which govern whether a customer will buy a color receiver or a black and white receiver. Moreover, the adoption of the CBS color system will furnish a healthy incentive to all manufacturers to develop larger size direct-view color pictures. Efforts already expended in the development of a successful tri-color direct-view tube that has no limitation on size will be intensified, for a substantial competitive advantage would accrue to the company able to produce such tubes. All of the expert witnesses agreed that a direct-view tri-color tube if successfully developed could be utilized on the CBS color system.

13. The second matter we referred to in paragraph 6 of this report is horizontal interlace. The record is clear that if this technique is successfully developed for the CBS system, it can be added at a later date without affect-

ing receivers in the hands of the public. The addition of horizontal interlace will increase horizontal resolution on receivers with appropriate circuits. Receivers without such circuits would not receive the benefit of this additional resolution but they would continue to receive the same performance as to resolution that they enjoyed before the addition of horizontal interlace. If it had been possi- [fol. 451] ble to adopt bracket standards now, the Commission could at the time of adopting horizontal interlace (if it is determined that it should be adopted) determine whether to increase vertical resolution as well as horizontal resolution. Receivers with brackets could accommodate themselves to the new line rate. Since receivers without brackets could not be adjusted to a different line rate, our inability to adopt brackets at this time probably means that as a practical matter, when and if horizontal interlace is adopted for the color system, the improvement may be confined to horizontal resolution.

14. The third matter we referred to in paragraph 6 of this Report is utilization of receiver tubes with long persistence phosphors. The benefit which can be expected from long persistence phosphors is much brighter pictures with no objectionable flicker. Had it been possible to adopt brackets now, then if developments in the field of long persistence phosphors turned out to be sufficiently impressive, the Commission could consider lowering the field rate and increasing resolution without objectionable flicker. Since we are not able at this time to adopt bracket standards, improvements from long persistence phosphors might, as a practical matter, be limited to increasing brightness without objectionable flicker.

15. The fourth matter we referred to in paragraph 6 of this Report is the possibility of new compatible color systems and improvements in existing color systems which have been informally called to our attention since the hearings closed. In the Commission's opinion a new television system is not entitled to a hearing or a reopening of a hearing simply on the basis of a paper presentation. In the radio field many theoretical systems exist and can be described on paper but it is a long step from this process [fol. 452] to successful operation. There can be no assurance that a system is going to work until the apparatus has been built and has been tested. None of the new systems or

improvements in systems meet these tests so as to warrant reopening of the hearing. To do so would be inviting the risk that these new systems might fail as have all color systems in the past which we have been urged to adopt on the grounds of compatibility and the increase in number of receivers in the hands of the public would make it exceedingly difficult to adopt an incompatible system—a system which we know is satisfactory.

16. The Commission does not imply that there is no further room for experimentation. Radio in general and television in particular are so new that extensive experimentation is necessary if the maximum potentialities of radio and television are to be realized. Many of the results of such experimentation can undoubtedly be added without affecting existing receivers. As to others some obsolescence of existing receivers may be involved if the changes are adopted. In the interest of stability this latter type of change will not be adopted unless the improvement is substantial in nature, when compared to the amount of dislocation involved. But when such an improvement does come along, the Commission cannot refuse to consider it merely because the owners of existing receivers might be compelled to spend additional money to continue receiving programs.

17. It is, therefore, contemplated that interested persons may conduct experimentation in accordance with experimental rules not only as to color television but as to all phases of television broadcasting. Of course, any person conducting such experimentation should realize that any new color system that is developed for utilization on regu- [fol. 453] lar television channels must meet the minimum criteria for a color television system set forth in our First Report. In addition, any such system that is developed or any improvement that results from the experimentation might face the problem of being incompatible with the present monochrome system or the color system we are adopting today. In that event, the new color system or other improvement will have to sustain the burden of showing that the improvement which results is substantial enough to be worth while when compared to the amount of dislocation involved to receivers then in the hands of the public.

18. For the reasons set forth in our First Report and in this Report, we find that the public interest will be served

by adopting the field sequential color television system. An appropriate order is accordingly being issued simultaneously with this Report.

Federal Communications Commission,* T. J. Slowie, Secretary.

Adopted: October 10, 1950
Released: October 11, 1950

[fol. 454] Dissenting Opinion of Commissioner Geo. E. Sterling

In the First Report of the Commission on the Color Television issues, I joined with the majority in the proposal for bracket standards with the understanding that if an insufficient number of assurances were received from manufacturers concerning their plans for incorporating bracket standards in their receivers, the Commission would issue a final decision adopting the CBS color standards.

Since the responses were not in accordance with the Commission's proposal, the majority have adopted the CBS color standards. I dissent from this premature action taken by the majority at this time for the following reasons.

The subject of bracket standards was not at issue in the hearing nor was the subject even advanced during the hearing. There is no doubt in my mind that manufacturers were taken by surprise at the Commission's approval on this subject as set forth in the First Report.

I do not agree with the majority in their Second Report that the responses of the manufacturers were merely a restatement of the parties' contentions made during the hearing, since the subject of bracket standards was a new concept in field and line scanning proposed after the hearing record closed. It came as a surprise to industry and was not based upon information appearing in the record of this proceeding.

Several manufacturers were confused by the Report as it related to bracket standards and representatives of different manufacturers communicated and met with the staff at various times for the purpose of securing an interpre-[fol. 455] tation of the Commission's intent. The exchange of correspondence with the Philco Corporation subse-

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* Commissioners Sterling and Hennock Dissenting.

quently made public is a classic example of the confusion aroused in the minds of manufacturers who evidenced a sincere interest in the problem.

The Columbia Broadcasting System found it necessary in this respect to voice its concern as to the interpretations that might be made of paragraph 5(c) and therefore consulted with the staff for clarification of the language. CBS also suggested that the Commission make clear by public statement what was intended by the language of paragraph 5(c).

Because bracket standards were new, I am now of the opinion that the Commission should have treated the subject at greater length in its First Report. Because of the time lost in seeking clarification of the Commission's intent and the necessity of meeting the September 29th deadline, manufacturers were unable to make a full appraisal of how they could build in bracket standards and when.

The response of Capehart-Farnsworth Corporation, I think, truly poses the problem confronted by manufacturers who are desirous of cooperating with the Commission, since it encompasses not only design and production of TV receivers embodying bracket standards capable of meeting the Commission's requirements as to geometric linearity and brightness but also points up the necessity of procuring signal generating equipment for the purpose of testing receivers incorporating bracket standards.

The Capehart-Farnsworth Corporation's response stated, in part, as follows:

> "We are having some difficulty in obtaining pictures of geometric linearity and brightness on the [fol. 456] higher frequencies and, in particular, we are faced with problems such as return time of the horizontal sweep and consequent reduced scanning efficiency. Other problems involve the loss of high voltage due to high frequencies with the deflection components now used and it is evident that new components, such as the deflection yoke and transformer, will have to be designed in order to meet the requirements stated in paragraph 151 of the Commission's Report 50-1064.
>
> "Also, until adequate signal generating equipment becomes available and until such times as the composite signal standards have been set, with particular reference to horizontal and vertical blanking time, we would

be unable to produce a product design which would assure satisfactory operation for both the monochrome and color television transmissions.''

The serious problems that confronted the Belmont Corporation, who also expressed a desire to cooperate, are stated, in part, as follows:

''We have been unable to find any record in technical literature nor in our past experience of an attempt to produce a linear sweep for electro-magnetic deflection systems covering the wide range of the proposed bracket requirement and at the same time adhering to the proposed requirements of constant picture size and brightness. Moreover, the major effort of our engineering department since the publication of Notice 50-1065 has failed to indicate any method of accomplishing the bracket standards. The standards called for by the notice create a far different problem from [fol. 457] that of incorporating in television receivers dual sweep systems permitting switching between specific standards, a system which probably could be engineered in the present state of the art.

''While Belmont has every desire to cooperate with the Commission in developing bracket standards, which are feasible from both the cost and engineering standpoints, it is clear from the above and from the results of our engineering survey that this cannot be accomplished within the time contemplated in the Commission's time schedule. Before Belmont could begin to manufacture television receivers with such standards, a method feasible from the engineering standpoint would have to be developed, the new equipment designed and field tested, a re-tooling operation accomplished, additional materials obtained and production methods revised. Hence, it would not be possible to be in production of receivers incorporating such bracket standards for a very much lonegr period than that contemplated by the Commission's time schedule.''

The problems of industry in terms of time are also succintly set forth in the response of Motorola, Inc., in which they stated:

''Motorola's approach to this entire matter is in the spirit of cooperation, accomplishment and realism.

Therefore, I hope that you seriously weigh what we set forth herein when you come to a decision on this subject.

"We are thoroughly convinced that the time allotted for a manufacturer to incorporate bracket standards into his production is inadequate. To further acquaint [fol. 458] you with Motorola's situation in this matter of time and to further demonstrate the inadequacy of the proposed time cycle, we are attaching herewith a report from our Engineering Division. This report is supported with two chronological histories taken at random from our Engineering Log Books. These histories set forth the mile posts of time for two engineering projects, that we classify as minor modification. The engineering principles involved in these two cases were generally known before the inauguration of the projects. Many of the technical principles involved in the integration of bracket standards require engineering development to reduce them to commercial practice. Therefore, we would like to make clear that the integration of bracket standards into our manufacturing is not a minor modification. In fact, bracket standards covering the full range require a complete chassis redesign."

The Hallicrafters Co. in their response to the Commission stated they had made every effort to determine their ability to cooperate with proposals of the Commission and significantly pointed out:

"The design of a receiver which will operate on any combination of field or line scanning frequencies within the proposed brackets is something we do not know how to accomplish in the present state of the art. This design would follow considerable basic research for which we cannot estimate a completion date. Following the date of engineering release, a materials procurement cycle of two to four months must pass before actual manufacture can begin. These time factors coupled with whatever date the Commission might [fol. 459] choose to release an order establishing Bracket Standards will determine whether we can supply Bracket Standards receivers within 30 days of the Order."

Several manufacturers stress the need for field testing after receivers have been made by their engineering departments. In its Report the Commission stressed the need of adequate field testing. In its First Report rejecting the RCA system, the Commission placed emphasis on the fact that this system had not been field tested and made mention that the system introduces entirely new techniques into broadcasting. So do bracket standards and yet the Commission in its failure to consider a reasonable timetable deprives manufacturers of the opportunity to field test this new device and, therefore, has taken an inconsistent stand with its enunciation of the importance of this element in the evolution of a new system. Manufacturers have a responsibility to the purchasing public and one of the important criteria of meeting this responsibility is through field testing its products prior to introducing them to the public. The competitive forces in this industry are tremendous and as in all products designed for public acceptance a manufacturer rises or falls according to the merits of his product. In my opinion, part of a reasonable timetable should include the necessity of field testing bracket standards under varying conditions of reception, including temperature, humidity, signal strength, etc.

Neither the Commission nor its staff has the necessary experience in the design and manufacture of TV receivers. Consequently, the Commission must take the word of reliable manufacturers who were willing to cooperate but unable to meet the Commission's short timetable. In its First [fol. 460] Report the Commission stated "that (it) is aware that of necessity it must rely to a great extent upon industry experts for data and expert opinion in arriving at decisions in the field of standards, our own facilities are too limited to gather much of the data"—paraphrasing this statement as it concerns bracket standards the Commission should say that it must take the word of industry as it concerns the design and production of bracket standards since it does not have the "know-how". By providing for a reasonable timetable the Commission would have in the end the experience of industry in this new concept of field and line scanning and would be able to better judge what it would cost the public and if it would provide the avenues for improvement that might be made in the art.

The problems confronting manufacturers today in terms of production, procurement and manpower to meet the de-

mands of national defense are serious ones. Surely the responses of such reliable manufacturers must be given credence and consideration. It is well known that there are serious shortages of tubes and resistors as well as basic materials. The situation on procurement is so acute that manufacturers have been shipping their TV receivers without a full complement of tubes, trusting to their dealers to procure them in local markets but the local market supply has been exhausted as the result of not only the local demands but as the result of the purchasing agents and manufacturers' representatives combing every territory in their search for components in short supply. At least one company has agents in Europe attempting to purchase resistors. This condition aggravated by others is bound to have a serious effect on production and will serve only to delay the availability of parts to make not only bracket standards but also parts with which to build adapters, converters and color receivers. Moreover, in many instances [fol. 461] industry has been required to divert its TV engineering experts to problems of production for defense because of the close relation of TV techniques to radar and other electronic devises the Government requires.

After a thorough study of the responses and taking into consideration the current problems of industry, I am convinced that the Commission's timetable presented to industry in its First Report to build in bracket standards was unreasonable. I think much could be accomplished in the interest of all concerned if we called a two-day conference with those members of the industry who indicated a willingness to cooperate with the Commission for the purpose of exploring the problem of bracket standards looking to a realistic timetable that could be met by industry without unduly aggravating the compatibility problem.

In the period that has passed since the manufacturers submitted their replies to meet the September 29th date line, I feel certain that they have continued their study of the problem and would be in a position at the end of a two-day conference with the Commission and staff to agree on a reasonable timetable similar to that proposed by the Commission in its First Report had manufacturers met the requirements of the Commission's proposal. Surely, this would be more timely than after a hearing at some subsequent date and the Commission then decided

to adopt bracket standards. If such a conference did not result in a practical solution of the problems I have discussed, I would then join the majority in authorizing the field sequential system.

If as the result of a hearing at some later date, bracket standards are adopted by the Commission, manufacturers [fol. 462] will be faced with the problem of redesigning and re-tooling in order to build such circuitry in receivers. Such a course of action on the part of the Commission will serve to slow up production and place hardship on manufacturers and will compound the confusion in the public mind, particularly those of the public that purchase a color receiver having dual standards since they will then possess receivers which will be unable to utilize the improvements made possible by the adoption of bracket standards. In the event that such improvements result in a change in scanning rates which fall outside the scope of the dual standards here adopted, those sets will be incompatible.

The Commission proposed a way to keep the door open for demonstrations of new systems, improvements of existing systems that came to light after the hearing record had closed, and demonstrations of the CBS system on large-size tri-color tubes of two or three manufacturers. Because the Commission would not take time to discuss with representatives of the industry who indicated a willingness to cooperate, the door has been closed.

In its First Report the Commission stated:

> "Since there was no demonstration on the record of a direct view tri-color tube on the CBS system, the record does not contain a definitive answer as to whether direct view tubes larger that 12½ inches are possible with the CBS system. Thus two difficult courses of action are open to the Commission. The first course of action is to reopen the record and to have a demonstration on the record wherein a tri-color tube or other technique for displaying large size direct-view pictures could be tried out on the CBS system."

[fol. 463] The record indicates that present color phosphors such as are used with tri-color tubes would not yield the same fidelity that is possible from filters as employed with the CBS disc receivers. By providing a reasonable timetable without seriously aggravating the compatibility

problem such a demonstration could have been made on the record and the question resolved once and for all.

By closing the door at this time the Commission also passed up the opportunity to provide a means of increasing the resolution of color pictures by lowering the field rate without objectionable flicker through the use of long persistence phosphors.

As a result of the Commission's action in immediately adopting CBS standards, proponents of new or improved systems must now look to an experimental license to do their testing and demonstrating. The Commission has stated in its Second Report a new color system or other improvements will have to sustain the burden of showing that improvements which result are substantial enough to be worthwhile when compared to the amount of dislocation involved to receivers then in the hands of the public. Therefore, we see that the public and industry at some later date again may be faced with the problem of compatibility.

The door also has been closed on the opportunity of taking one more look at compatible systems before moving to adopt an incompatible system with all its attendant problems as they relate to the 10 million receivers that will be in the hands of the public by the end of the year as well as the manufacturers' problem of production.

I joined with the majority in the First Report with regard to what was said about the problems that seemed to confront a compatible color system and with the conclusion that no satisfactory compatible color system had [fol. 464] been developed at the time the record closed.

New developments came fast in the closing days of the hearing and immediately thereafter.

It was pointed out in the First Report that the Commission is aware that the institution of the color proceedings stimulated great activity in color developments and that fundamental research cannot be performed on schedule, and that it is possible that much of the fruit of this research has begun to emerge. This is confirmed by the facts, which include the announcement of two new compatible systems and by the RCA Progress Report of July 31, 1950, that the number of dots in the RCA tri-color tubes has been increased from 351,000 to 600,000 with the attendant increase in resolution. Other improvements were also made in the RCA system after the record was closed.

I am convinced that it would have been prudent to have taken time out to view these recent developments before moving finally to adopt an incompatible system.

I find it necessary also to dissent from the belief expressed by the Commission in the Second Report and which was not in the First Report in which I joined with the majority. In paragraph 12 in the Second Report, the Commission states:

> "The Commission believes that the attractiveness of color pictures may be sufficiently great to cause people to prefer a direct-view receiver with a 12½ inch tube or a larger size projection receiver if they can get color as against a 16 inch, 19 inch or larger direct-view receiver that is limited to black and white pictures. * * *"

[fol. 465] I do not agree with this belief. I believe that the rapid acceptance by the public of receivers incorporating larger sized black and white tubes as they moved from 7" to 10" to 12", then to 16" and 19" clearly indicates the preference of the public for large size TV pictures and they will not be satisfied with smaller pictures because they are in color. Due to the fact that color adds so much to television both from the program as well as the advertising standpoint, both the public and the sponsor will demand large size color tubes.

## Dissenting Views of Commissioner Hennock

As I indicated in my separate views to the Commission's First Report on Color, I am of the firm belief that every possible effort should be made by this Commission and the television manufacturing industry to achieve a practical and useful compatible color television system. Considering the fact that there are currently well over 7,000,000 receivers in the hands of the public which can receive, in their present form, only signals broadcast on present monochrome standards, many grave problems will be posed by the adoption of the incompatible field sequential color television system. The owners of these sets must eventually suffer a diminution in television service or they will be forced to make some expenditure to adapt or convert their sets for the reception of color signals. The cost of such changes and the servicing difficulties which they will entail

pose a problem of great magnitude, and the end result in the case of adaption will be a monochrome picture of reduced resolution. The broadcaster will find that, to the extent that he employs color transmissions, he will lose part of his audience, and this will create a long and difficult period of transition.

[fol. 466] I agree with the Commission's evaluation of the color systems which have been proposed and demonstrated in the instant proceedings. I felt at the time of the First Report, and still feel, that, in the light of this evaluation, it is eminently desirable that the problem posed by the number of television receivers in the hands of the public as regards the incompatible field sequential color system be arrested at its present level. I believed that the concept of "bracket standards" set forth in the First Report was a practical method for achieving this end, and I therefore joined in that portion of the First Report.

The comments filed in response to our Second Notice of Further Proposed Rule Making indicate quite clearly that the bracket standards proposal is not a feasible method for containing the problem of incompatibility at its present level. Most of the comments did not indicate whether other means for achieving this aim are available, although a few did discuss possible alternative methods.

But in the light of the progress made in the development of color television since the start of the instant proceeding, I think it essential to defer final decision in this matter until June 30, 1951. This could still be done if some means for preventing the growth of incompatibility could be devised by the television manufacturing industry. The fact that bracket standards could not achieve this result does not automatically preclude its attainment. Possibly some modified version of bracket standards could be incorporated into television receivers without raising the major problems of re-design and equipment procurement involved by bracket standards. Or it might be feasible to provide adaptation—either internal or external—with each receiver. The manufacturing industry is familiar with this process since it has been for a considerable time a part of the record in this proceeding. The ingenuity [fols. 467-468] of the industry's electronic scientists might be able to devise some other means of arresting the problem of compatibility and thereby provide further time for the

development of a practical compatible color television system.

I feel that the Commission should explore fully with the industry any and all possibilities. This could be done either by means of an industry conference or by a Notice of Further Proposed Rule Making requesting comments. It is of vital importance to the future of television that we make every effort to gain the time necessary for further experimentation leading to the perfection of a compatible color television system. If as a result of such a conference or comments filed by the industry, it appears that steps can be taken within 60 or 90 days to arrest the growth of incompatibility, the final decision in this proceeding authorizing the field sequential system should be deferred until June 30, 1951. If not, those standards should be immediately adopted.

I think it important to repeat the conviction expressed in my separate views to the First Report that there is a moral obligation on this Commission to insure that a reasonable amount of valuable programming service will continue to be rendered to present set owners, both day and night, for a transitional period, e.g., three to five years, without the necessity for making any expenditure to change their sets.

[fol. 469] EXHIBIT H TO COMPLAINT

55655
FCC 50-1225

Federal Communications Commission
Washington 25, D. C.

In the Matters of

Docket Nos. 8736 and 8975

Amendment of Section 3.606 of the Commission's Rules and Regulations

Docket No. 9175

Amendment of the Commission's Rules, Regulations and Engineering Standards Concerning the Television Broadcast Service

Docket No. 8976

Utilization of Frequencies in the Band 470 to 890 Mcs. for Television Broadcasting

Order

At a session of the Federal Communications Commission held at its offices in Washington, D. C., on October 10, 1950;

The Commission having under consideration the promulgation of engineering standards for color television; and

It appearing that on September 1, 1950 the Commission issued (1) Findings and Conclusions in the above proceedings entitled "First Report of Commission (Color Television Issues)" (FCC 50-1064), and (2) its "Second Notice [fol. 470] of Further Proposed Rule Making" (FCC 50-1065); and

It further appearing that simultaneously with the issuance of this Order the Commission is issuing its "Second Report of the Commission" (FCC 50-1224);

Accordingly, on the basis of the findings and conclusions set forth in both of the above Reports,

It is ordered, that effective the 20th day of November, 1950, the Commission's "Standards of Good Engineering

Practice Concerning Television Broadcast Stations" are amended in the following respects:

(1) Paragraphs "5", "6", "7", and "8" of Section I B entitled "Visual Transmitter" are revised to read as follows:

5. Color transmission.—The term "color transmission" means the transmission of color television signals which can be reproduced with different values of hue, saturation, and luminance.

6. Field—The term "field" means scanning through the picture area once in the chosen scanning pattern and in a single color. In the line interlaced scanning pattern of two to one, it means the scanning of the alternate lines of the picture area once in a single color.

7. Frame.—The term "frame" means scanning all of the picture area once in a single color. In the line interlaced scanning pattern of two to one a frame consists of two fields.

[fol. 471] 8(a). Color field.—The term "color field" means scanning through the picture area once in the chosen scanning pattern and in each of the primary colors. In the line interlaced scanning pattern of two to one, it means the scanning of the alternate lines of the picture area once in each of the primary colors.

(b) Color frame.—The term "color frame" means scanning all of the picture area once in each of the primary colors. In the line interlaced scanning pattern of two to one, a color frame consists of two color fields.

(2) Paragraphs "5", "6" and "13" of Section 2 A entitled "Transmission Standards and Changes or Modifications Thereof" are revised to read as follows:

5. For monochrome transmission the number of scanning lines per frame shall be 525, interlaced two to one in successive fields. The frame frequency shall be 30, the field frequency 60, and the line frequency 15,750 per second.

6. For color transmissions the number of scanning lines per frame shall be 405, interlaced two to one in successive fields of the same color. The frame frequency shall be 72, the field frequency 144, the color